Successful Cases Analysis of Complex Carbonate Logs Interpretation of PetroChina

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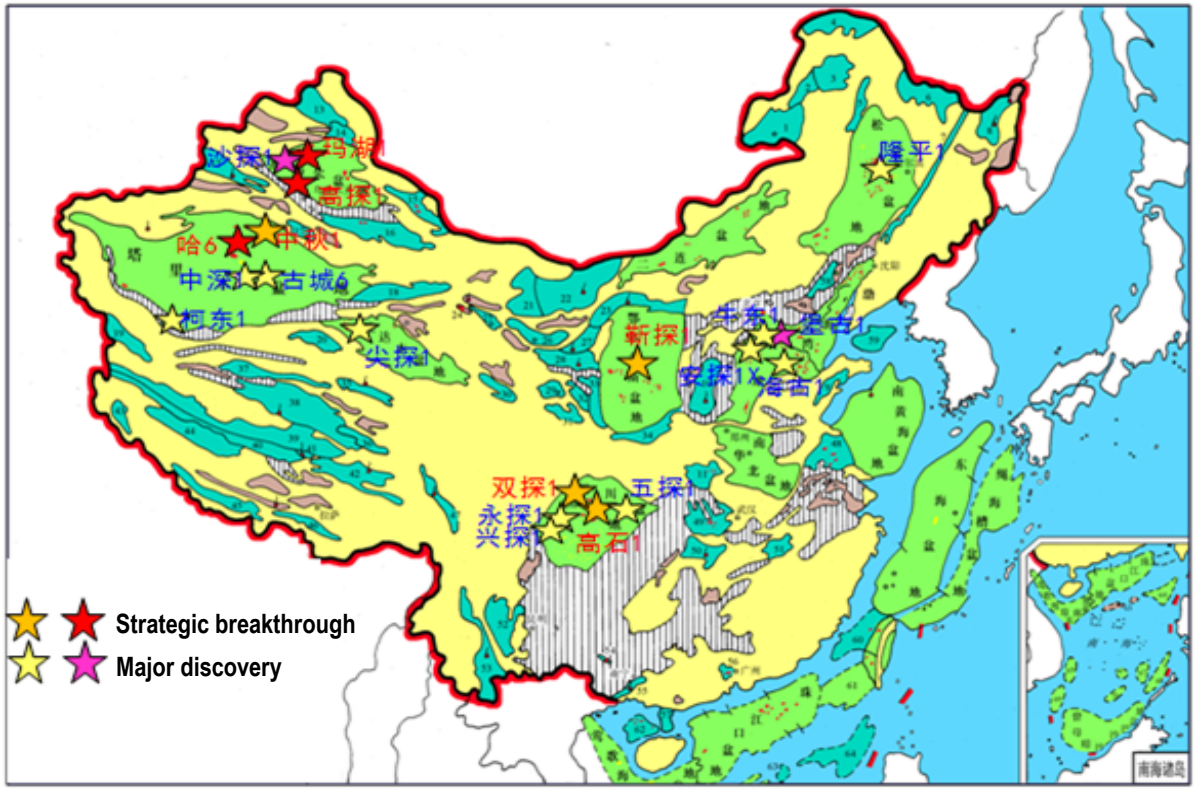
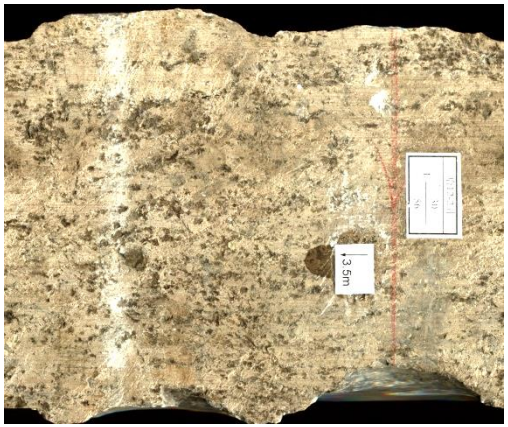
Outline

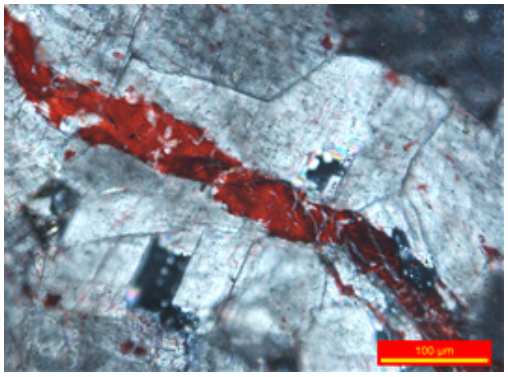
- Background introduction
- Evaluation of Inhomogenous Lacustrine Carbonate Reservoir
- Indentifying the reservoir nearby the borehole and fluid type interpretation
- Interpretation of Fracture-cave Carbonate Gas Reservoir filled with Asphaltum
- Summary

Background Introduction

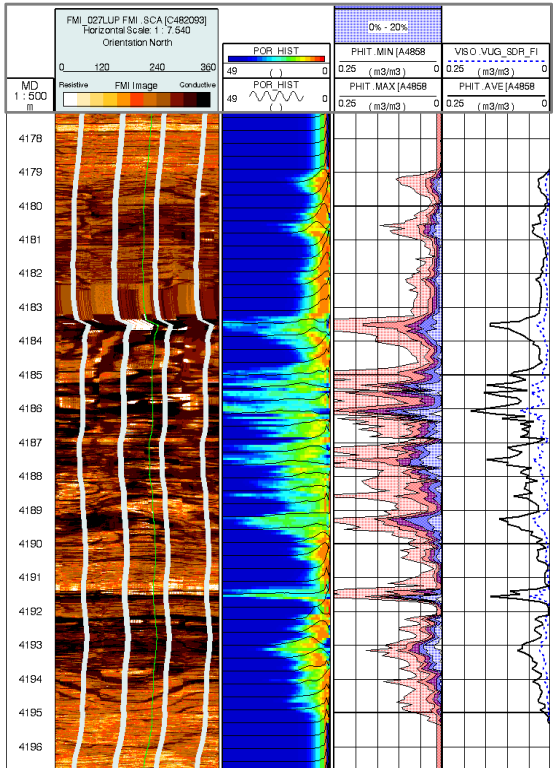
- PetroChina got a series success in deep-buried carbonate within last 10 years.
- Carbonate reservoir is characterized by ultra-low Φ/K with fracture and dissolved pore-cave as favorable target.

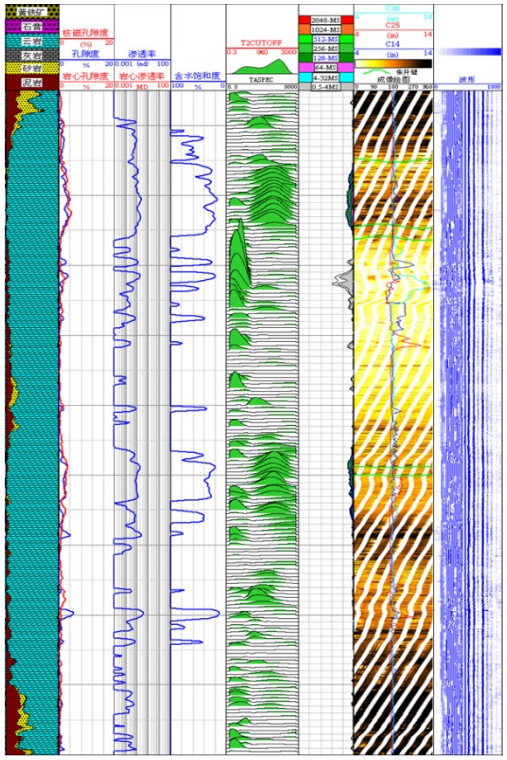


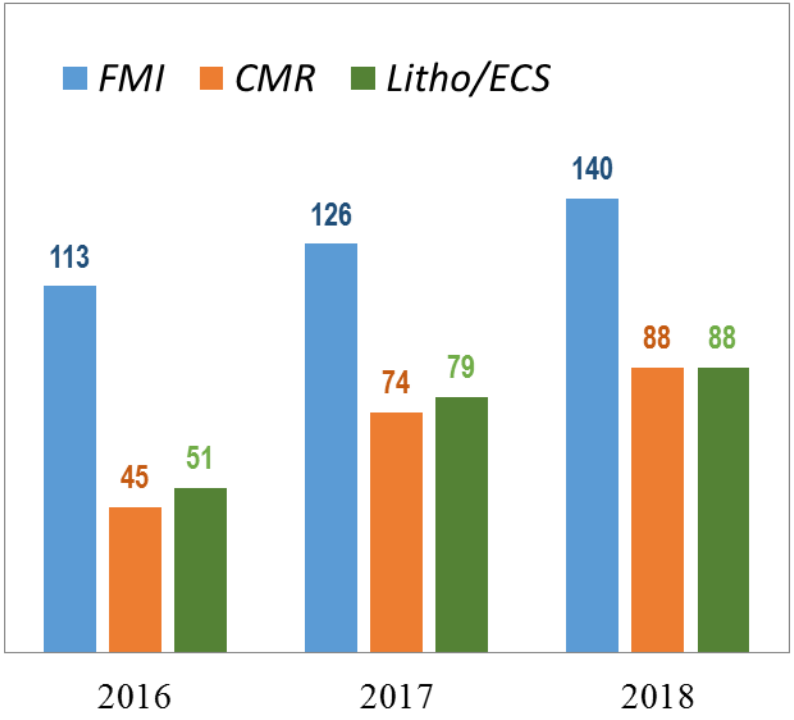




- Advanced and applicable logging technology, as FMI/LithoScanner/CMR, provided perfect solution for carbonate reservoir evaluation.
- Win-win cooperation between PC and SLB has been in steady advance.

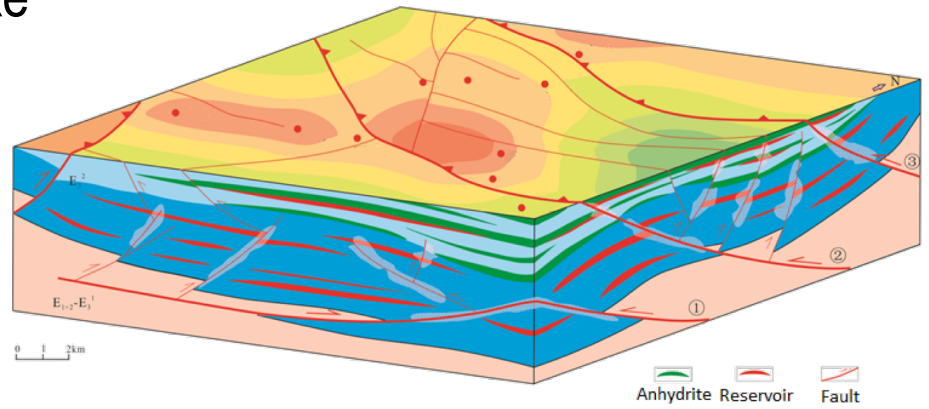


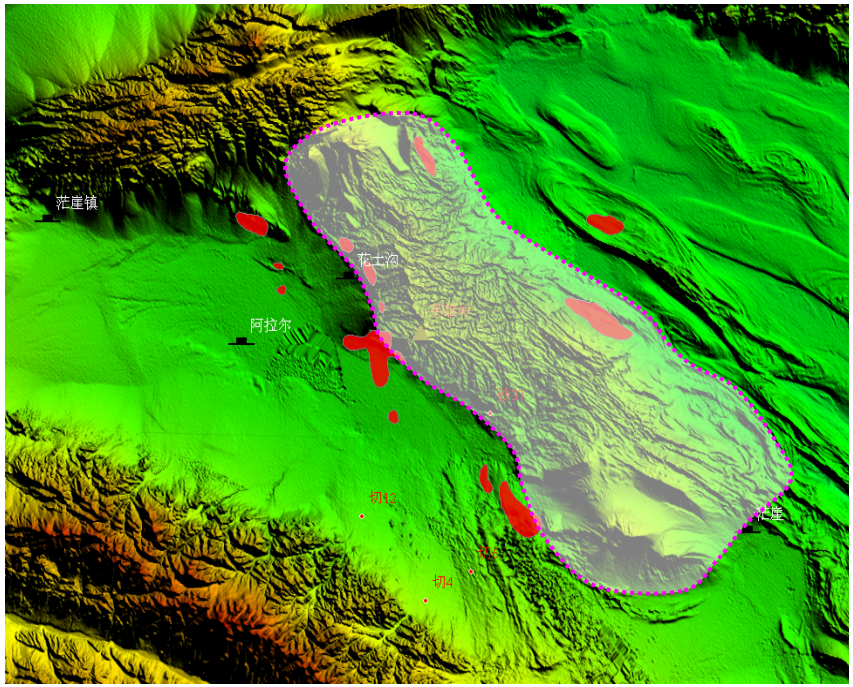


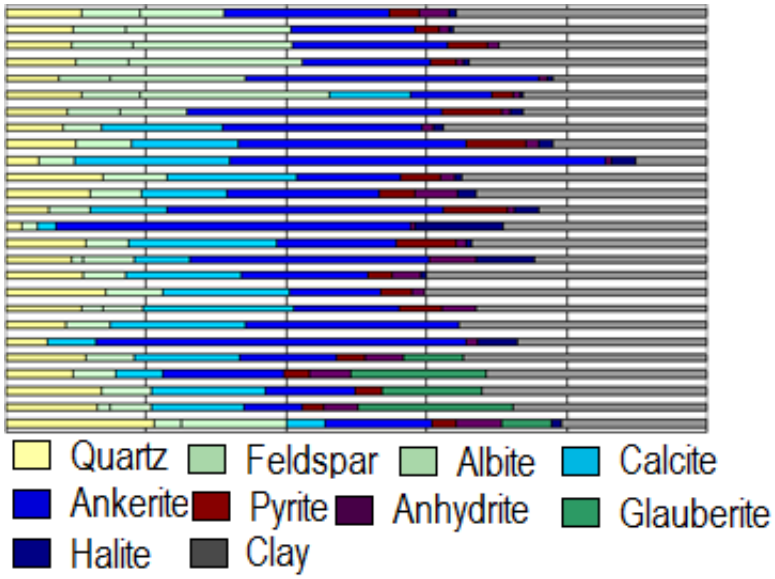


Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

- Yingxiongling area, located in west of Qaidam, northwest of China
- Pay zone is E_3^2, deposited in saline lake
- Complex lithology and pore-space hinder log interpretation







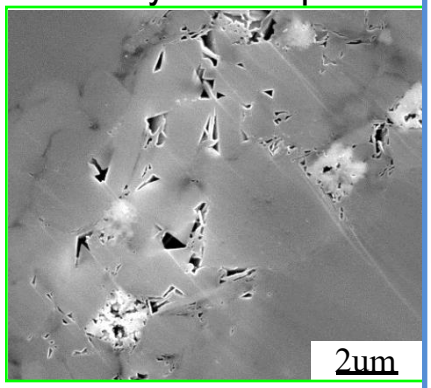
Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

- Pore space includes intercrystalline pores, dissolved pore, cave & fracture.
- The productivity depends mainly on total porosity and fracture porosity.
- Determining porosity and valuable pay zone is of great importance.

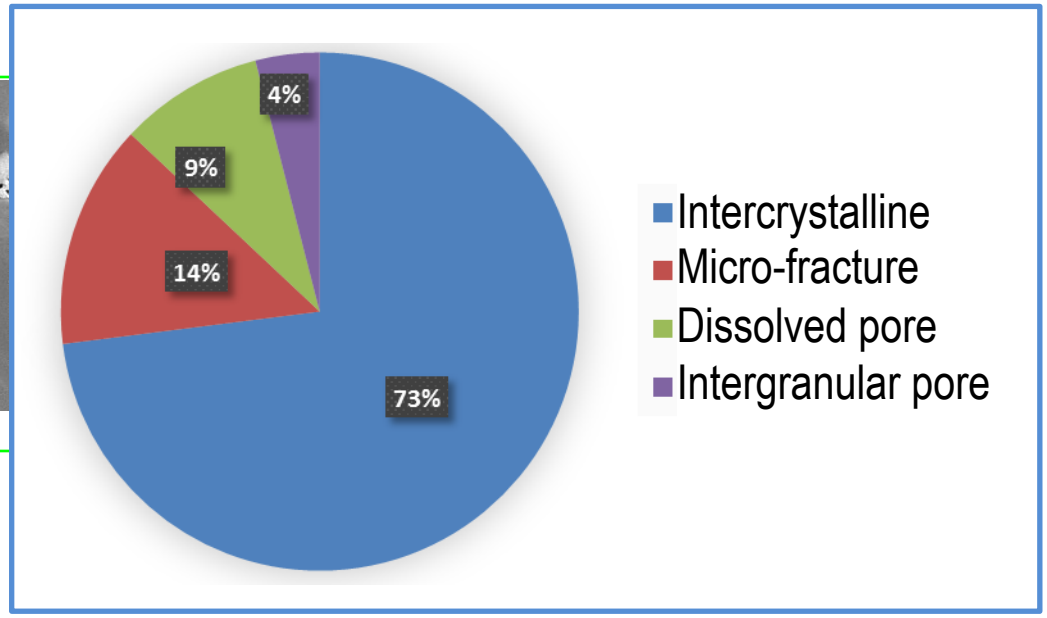
Permeability

Low → High

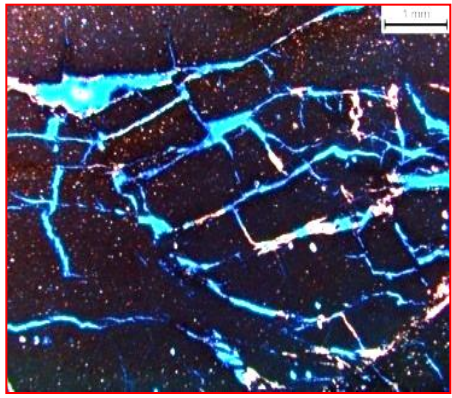
intercrystalline pores



Nanometer size

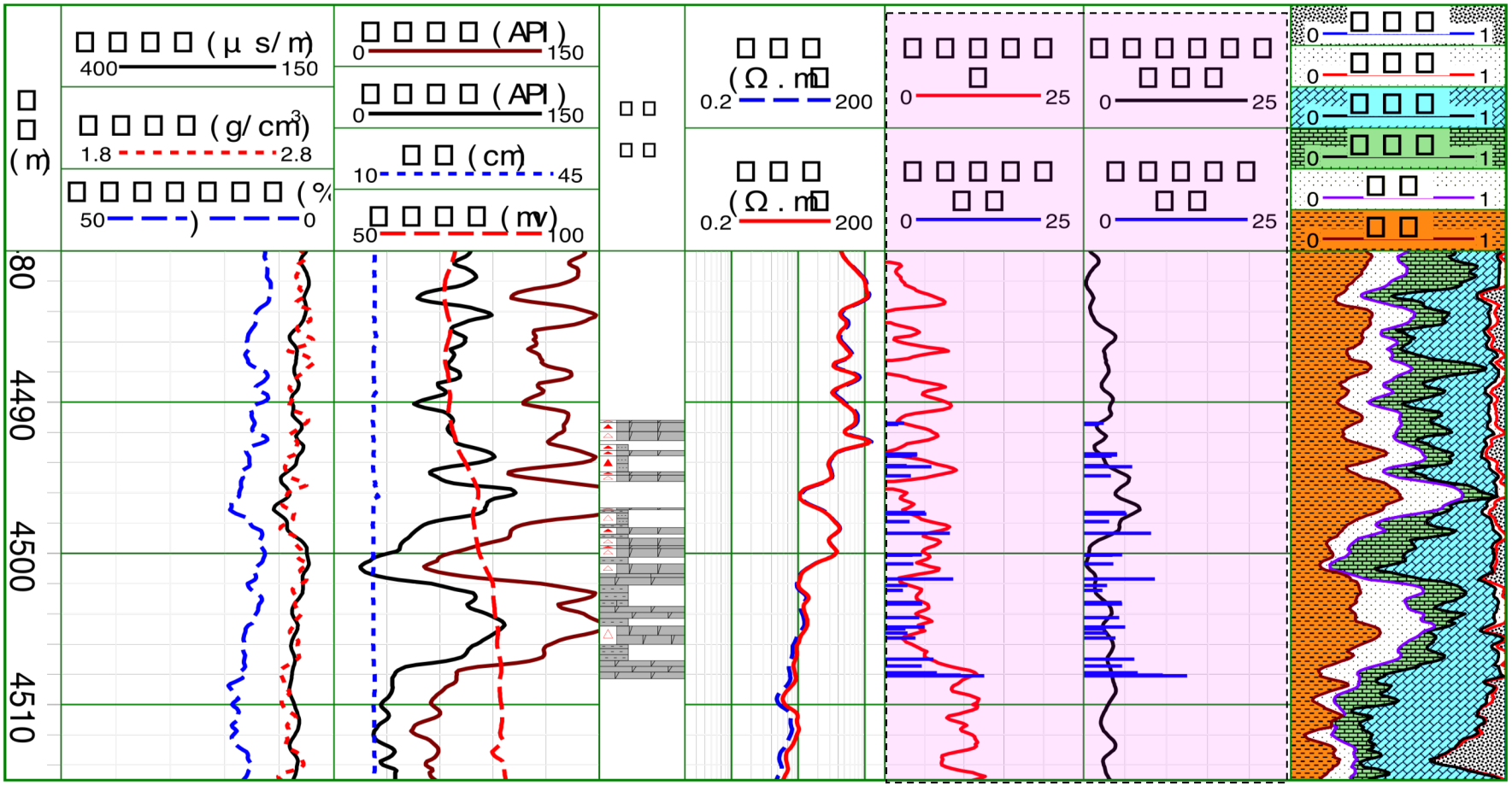


fracture



Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

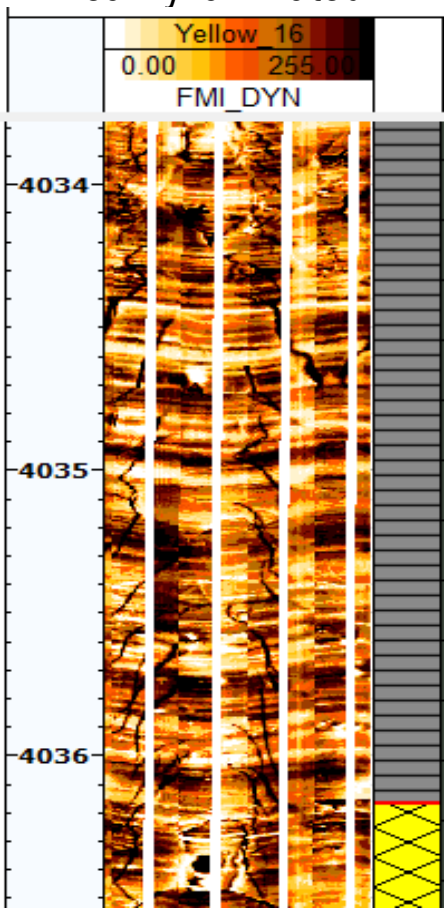
- LithoScanner provides detailed elements & mineral profile
- Based on ρ_{ma} from LithoScanner, the accuracy of φ_e is improved greatly.



Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

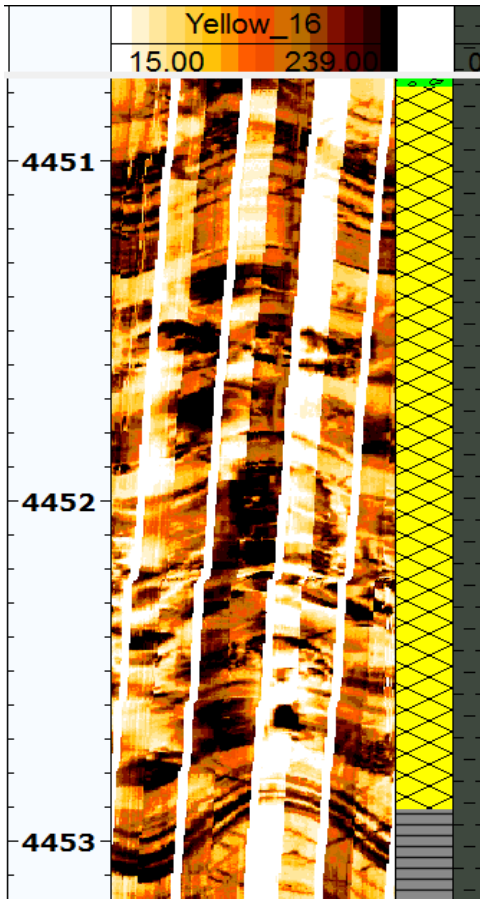
- The formation with block structure in FMI image is high-yield layer usually.
- Heavily laminated formation is dry zone.

heavily laminated



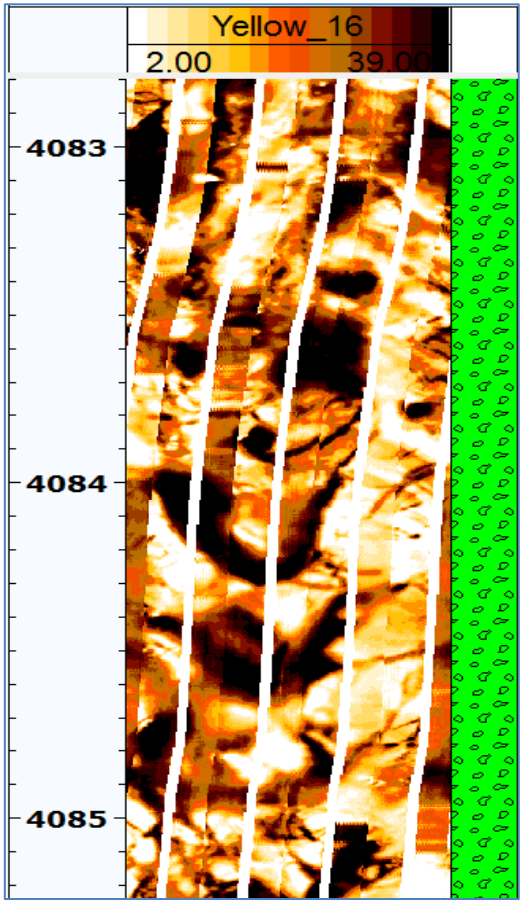
4034-4044m, dry

weak layered



4450-4460m, Oil 8m^3/d

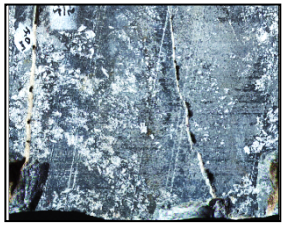
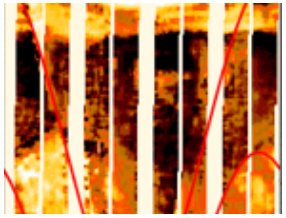
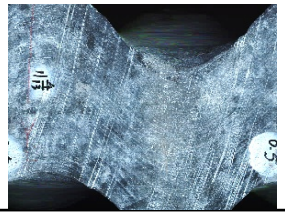
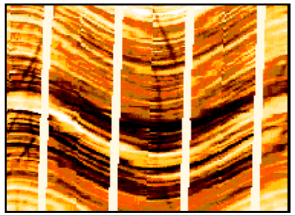
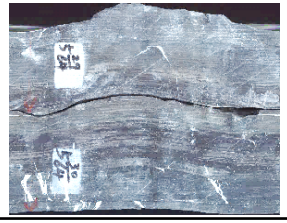
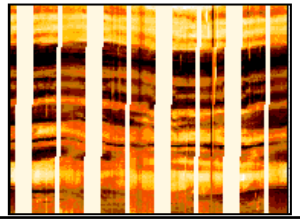
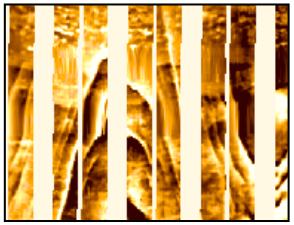
block with dark blobs



4073-4083m, Oil 55m^3/d

Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

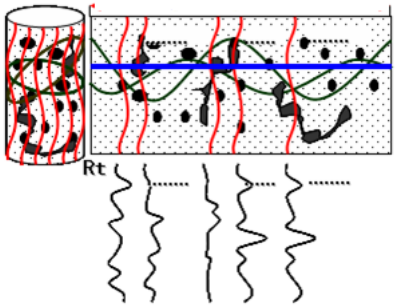
- By FMI image scaled with core, favorable reservoir is discriminated.

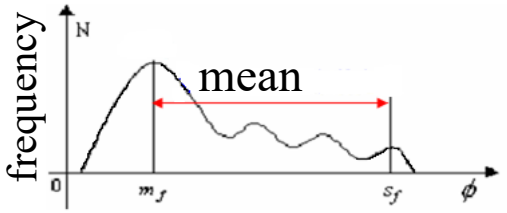
Classification	Core	FMI image	Description
block with dark blobs			dark blobs means dissolved pores and cave, accompanied by fractures
heavily laminated			well layered with constant dip, no cave and fractures
weak layered			layered with thick lamina, accompanied by fractures
Tight			Anhydrite gathering or fast deposition.

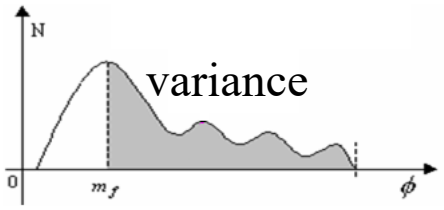
Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

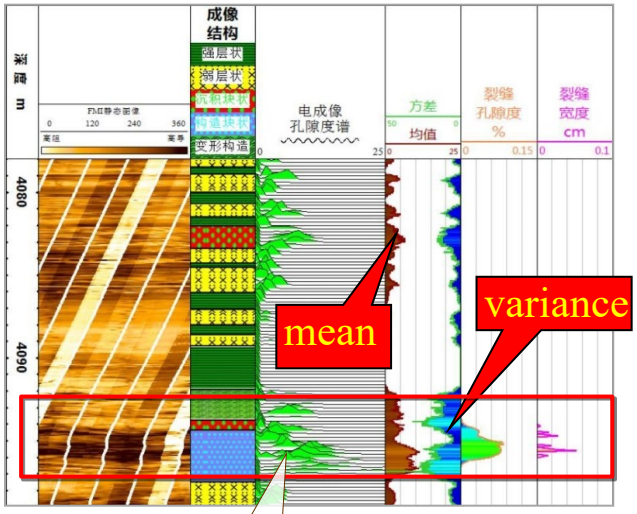
- Further, reservoir is classified into 3 types according to image spectrum.
  - **I:m≥4, V≥12**
  - **II:m≥4, 9≤V<12;**
  - **III:m≥4, 5≤V<9;**

Pay zone： 3%≤Φ<6%, FVPA≥0.03%

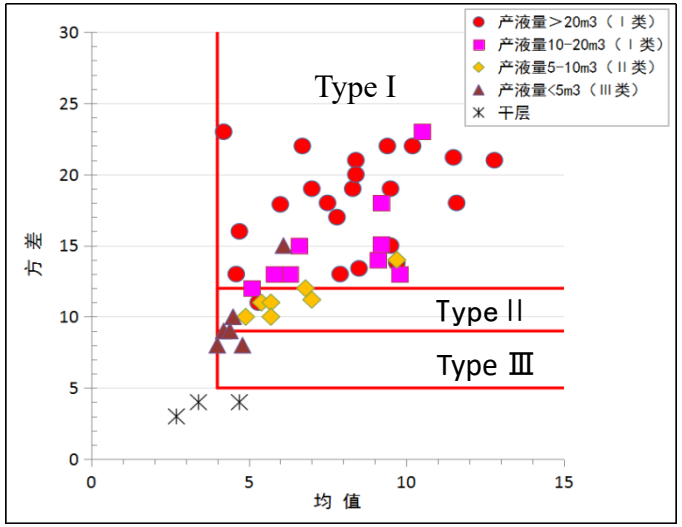






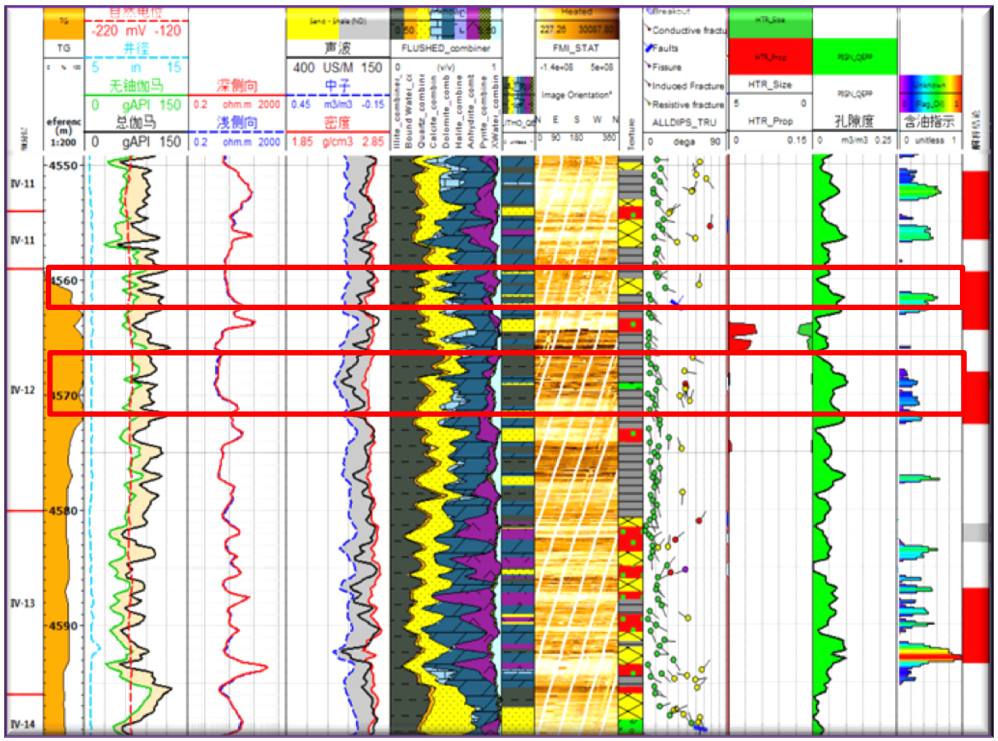


4090-4098m,
Oil 24.68m^3/d.

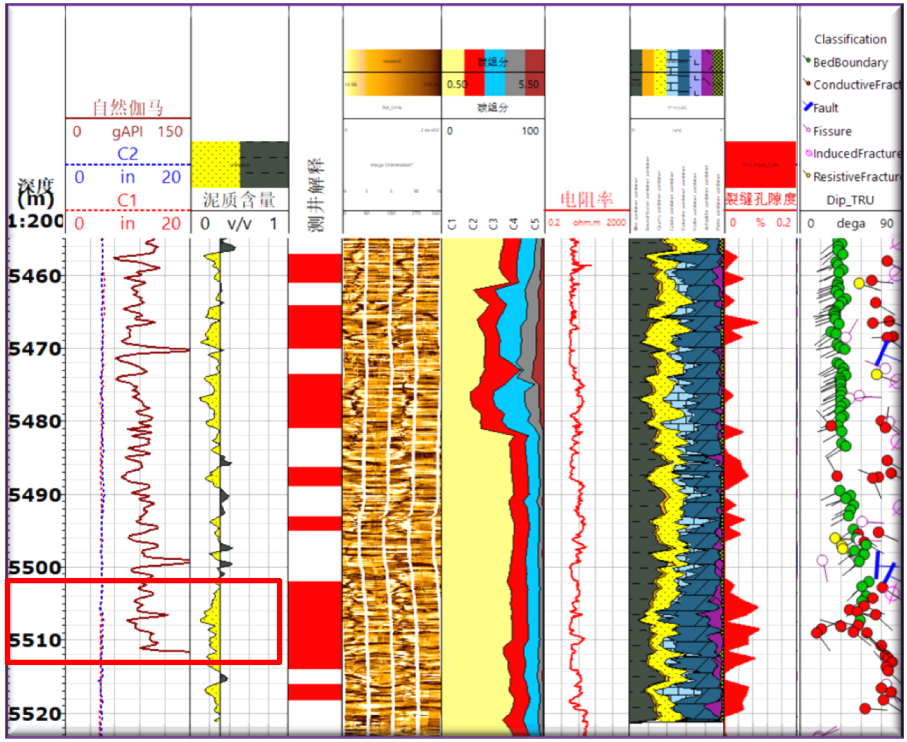


Part Ⅰ. Evaluation of Inhomogenous Lacustrine Carbonate Reservoir

- FMI/LitoScanner/CMR+ items have been introduced into this area in large-scale.
- Application of SLB technology improves the interpretation coincidence rate.
- Cooperation between Petrochina & Schlumberger is win-win.



Oil: 57m³/D

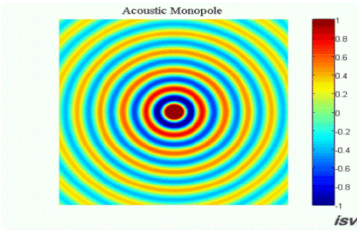


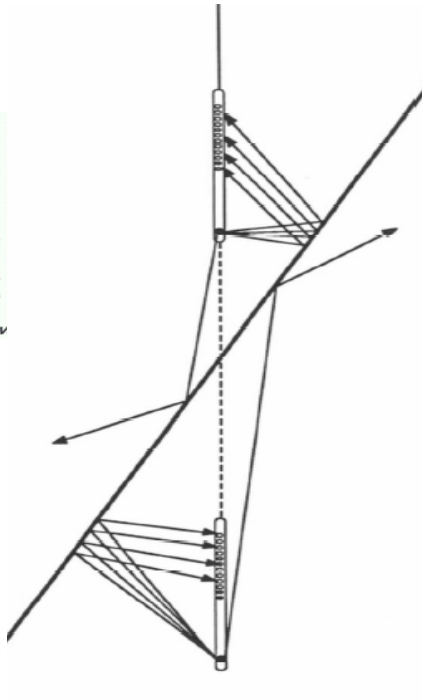
Oil: 205m³、Gas 70229m³/D

Part II . Indentifying the reservoir nearby the borehole and fluid type interpretation

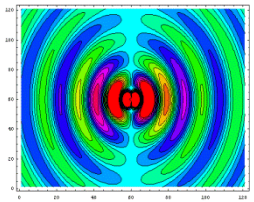
- Traditionnaly, remote acoustic reflection wave logging is based on reflected P-wave.
- The answer is uncertain in distance and direction only by P-wave from mono-pole.

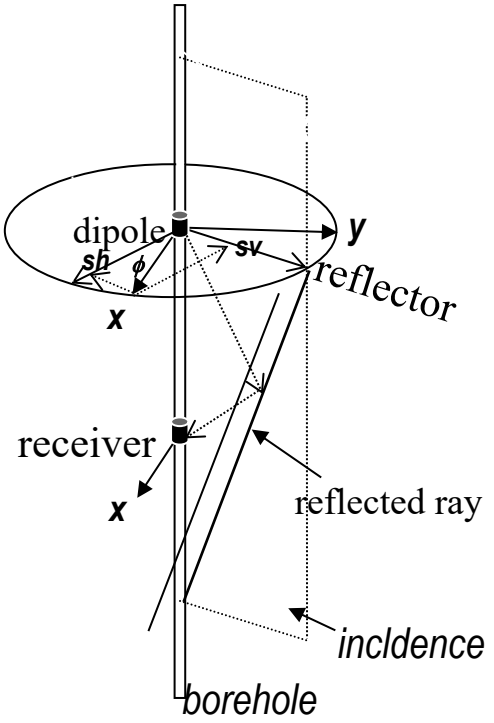
P-wave from mono-pole





S-wave from dipole





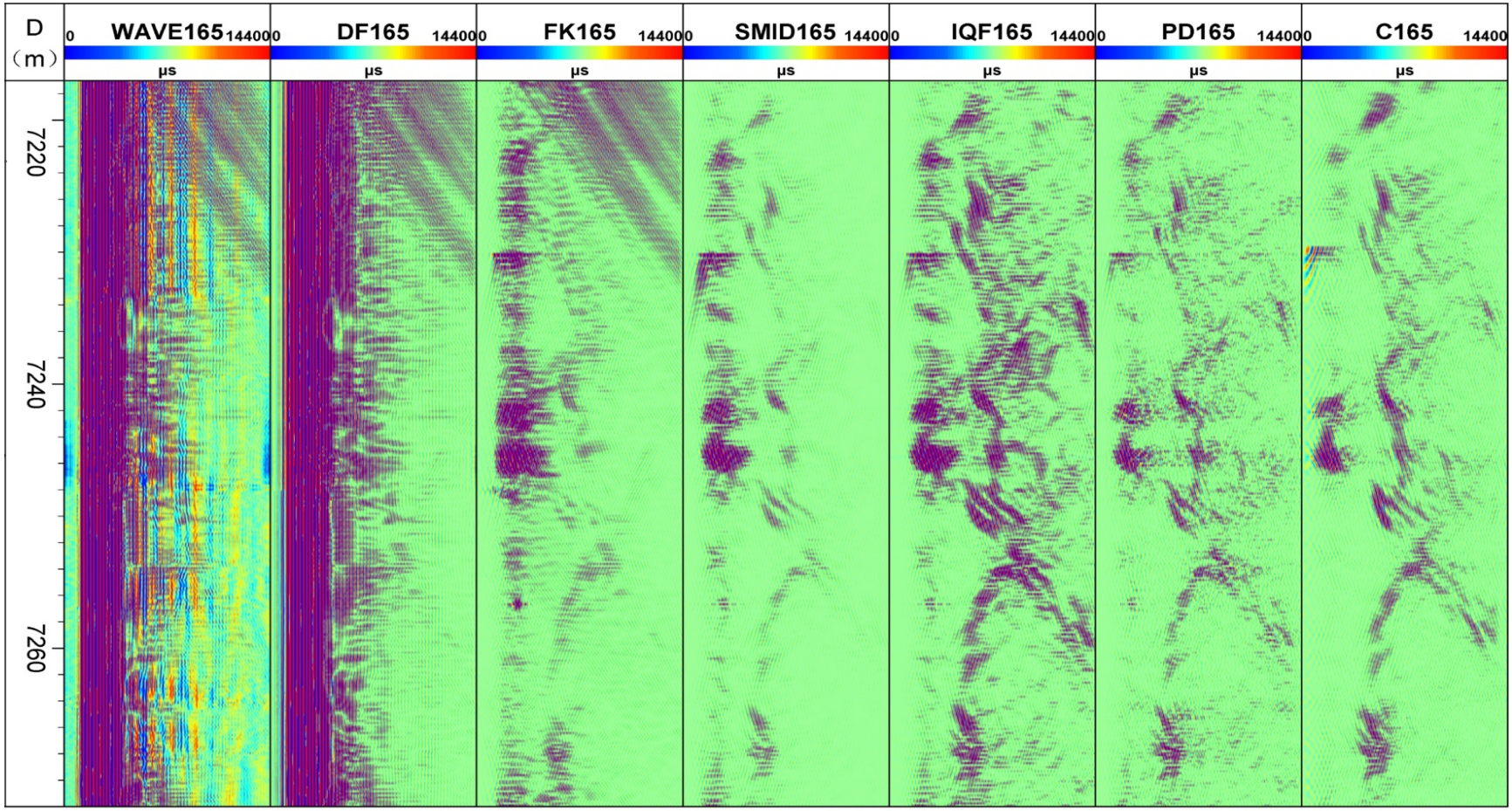
Part Ⅱ. Indentifying the reservoir nearby the borehole and fluid type interpretation

- Different type of noise is summarized and corresponding solution is provided for cleanning image.

Noise	Noise Type	Response	Solution
relevant	borehole wave	△t is constant	F-K filtering
	Bad channel	borehole radius increase	Bad channel identification & resorting
	interface reflected wave	Great change in GR log	median filtering
irrelevant	circuit noise	Signal with low frequency and large amplitude （<1.5kHz）	Digital bandpass filtering
	Multiple wave	obvious trailing in direcct wave	deconvolution
	others	Discrete noise	Superposition

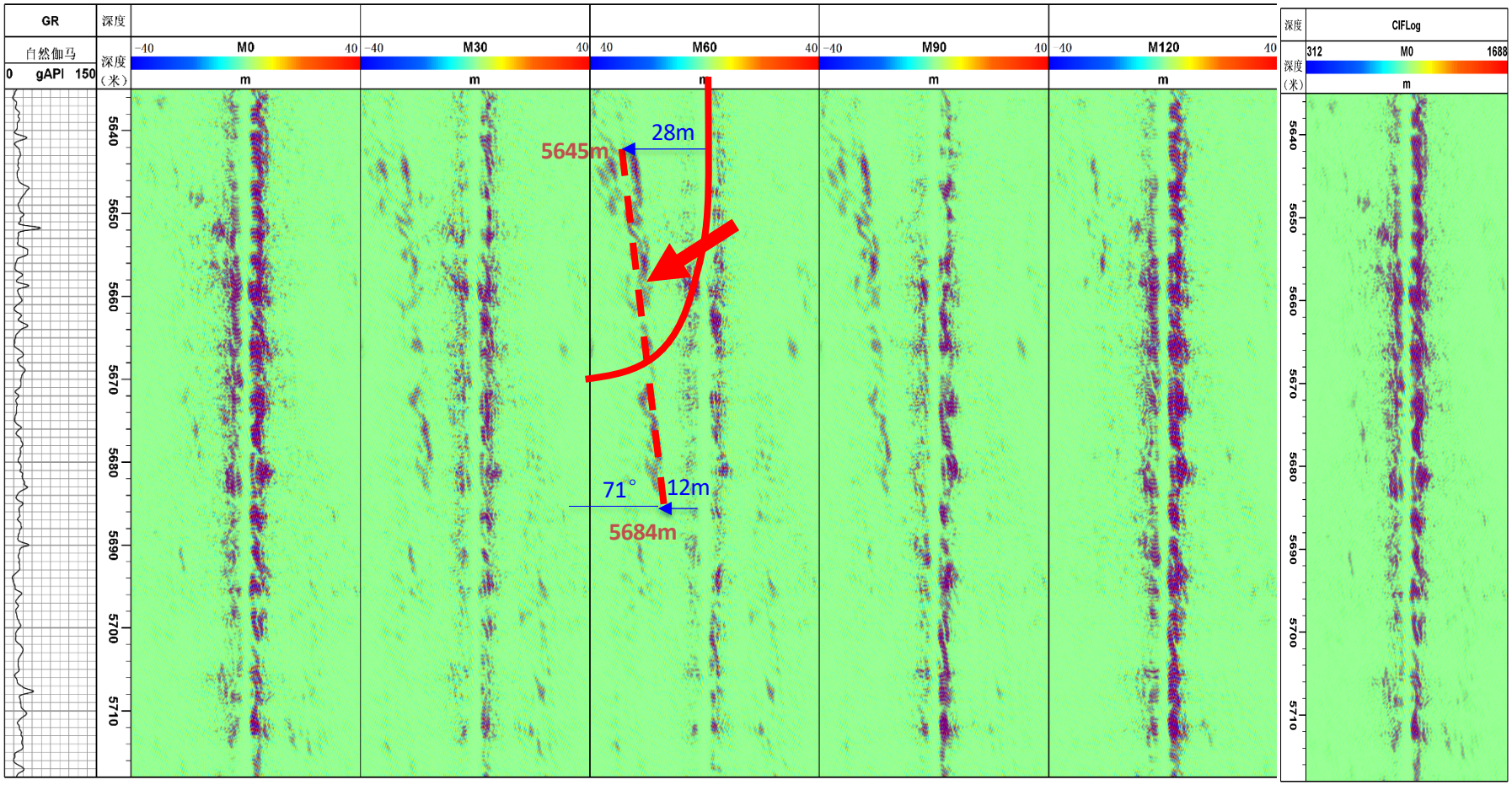
Part Ⅱ. Indentifying the reservoir nearby the borehole and fluid type interpretation

- By noise suppression step by step, accurate reflected S-wave image is obtained



Part Ⅱ. Indentifying the reservoir nearby the borehole and fluid type interpretation

- Based on clean image we can define reflector and find reservoir behind the borehole.
- Then by sidetracking and we got oil & gas production.



Well of ZG7-5

Part Ⅱ. Indentifying the reservoir nearby the borehole and fluid type interpretation

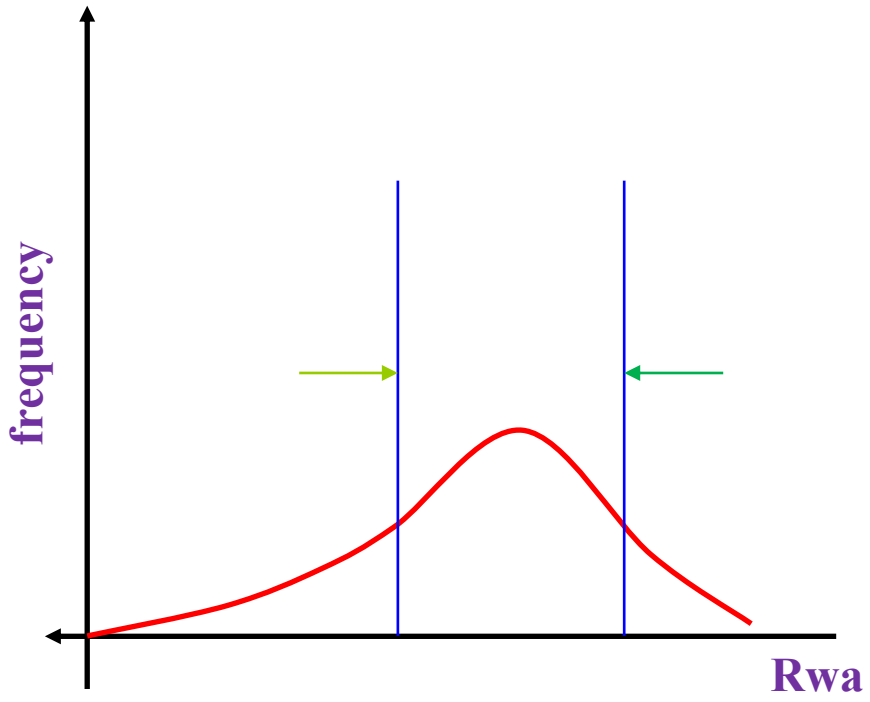
- From FMI, 192 Rt logs are obtained and then Rt is converted into Rwa.
- From the distribution of Rwa we can infer the fluid type.

Median

$$\overline{R_{wa}} = \sum_{i=1}^{n} R_{wai} P_{R_{wai}} \Big/ \sum_{i=1}^{n} P_{R_{wai}}$$

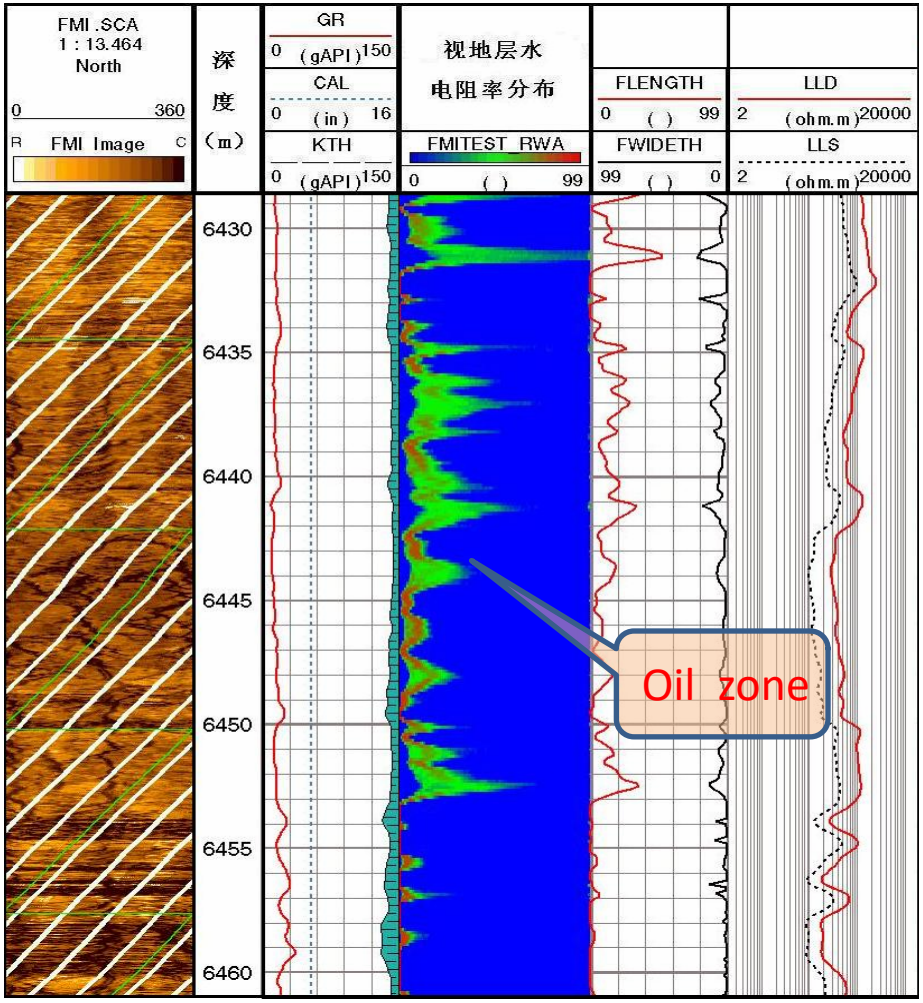
variance

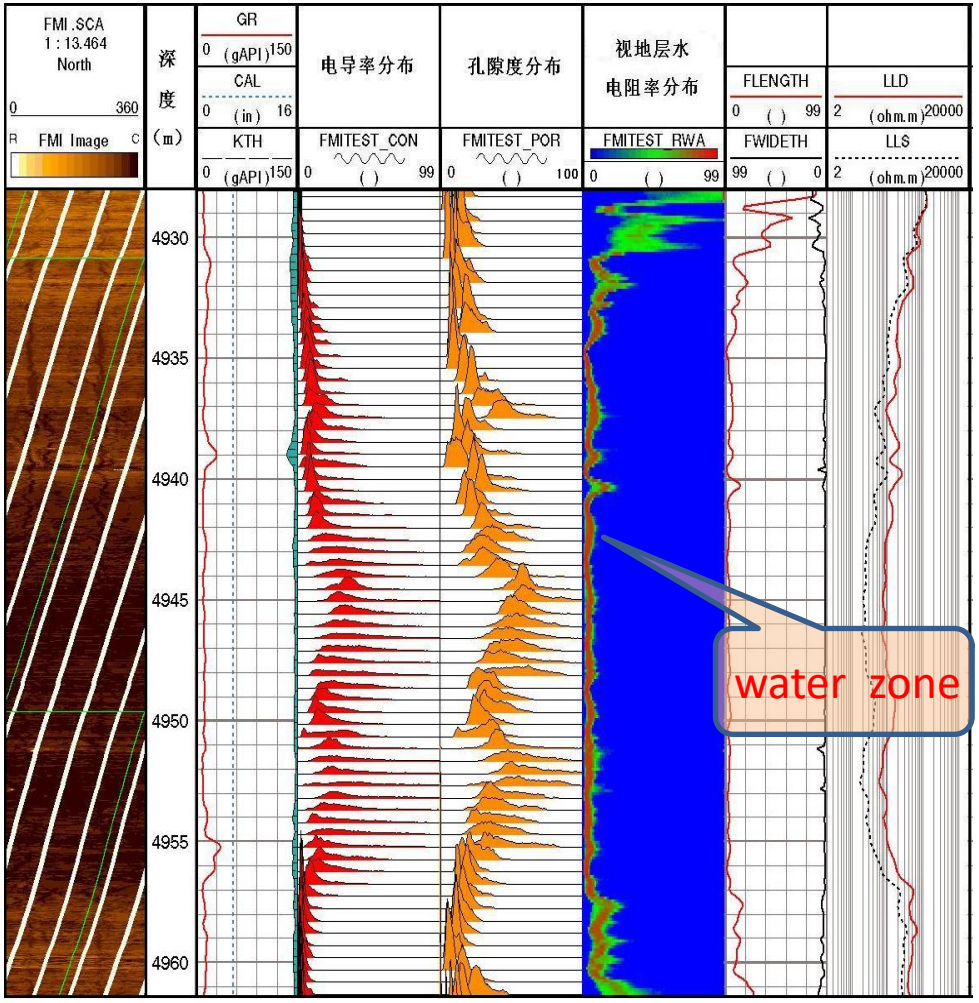
$$\sigma_{R_{wa}} = \sqrt{\frac{\sum_{i=1}^{n} P_{R_{wai}} (R_{wai} - \overline{R_{wa}})^2}{\sum_{i=1}^{n} P_{R_{wai}}}}$$



Part Ⅱ. Indentifying the reservoir nearby the borehole and fluid type interpretation

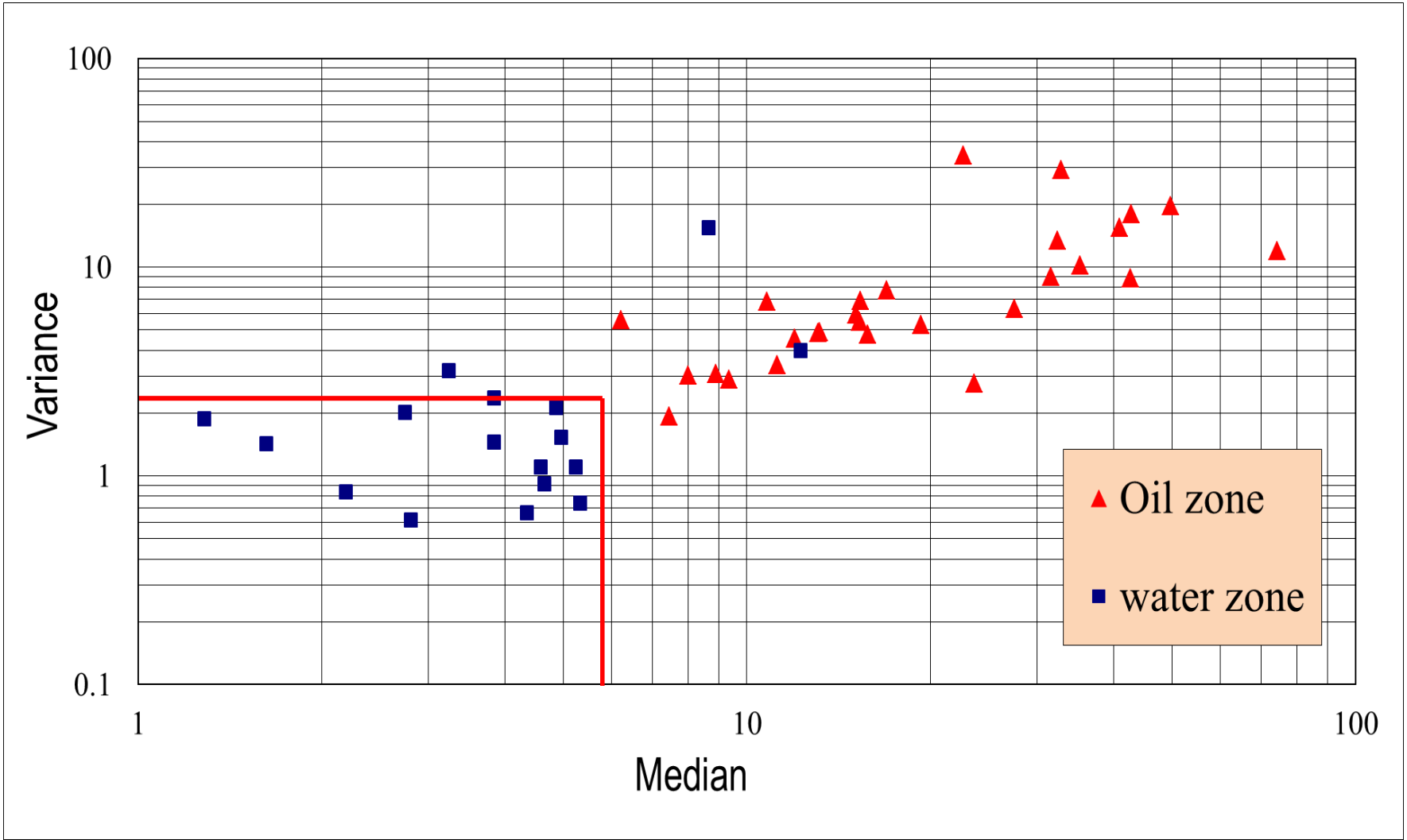
- From the Rwa spectrum analysis, some difficult zones are interpreted successfully.





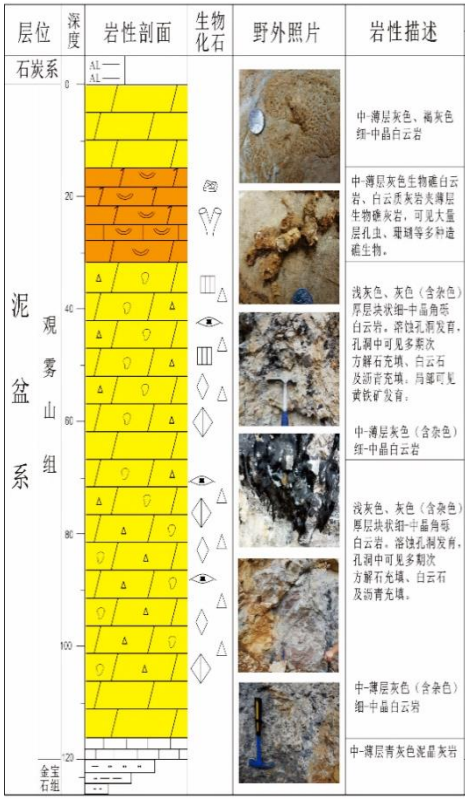
Part Ⅱ . Indentifying the reservoir nearby the borehole and fluid type interpretation

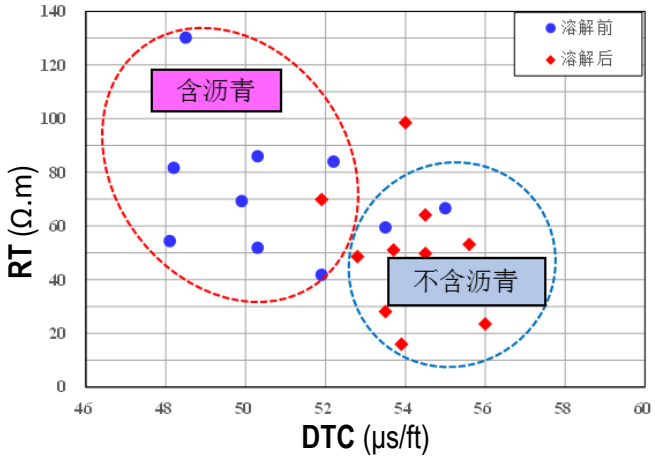
- By FMI scaling, criteria for pay zone interpretation is defined and the coincidence rate of carbonate reservoir is improved greatly.

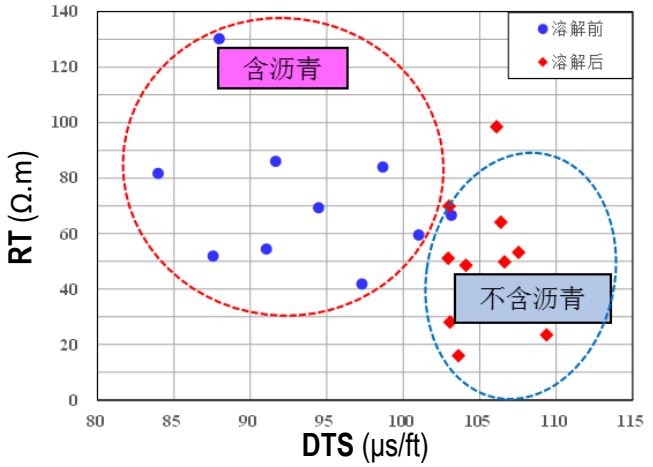


Part Ⅲ. Case of Carbonate Gas Reservoir filled with Asphaltum

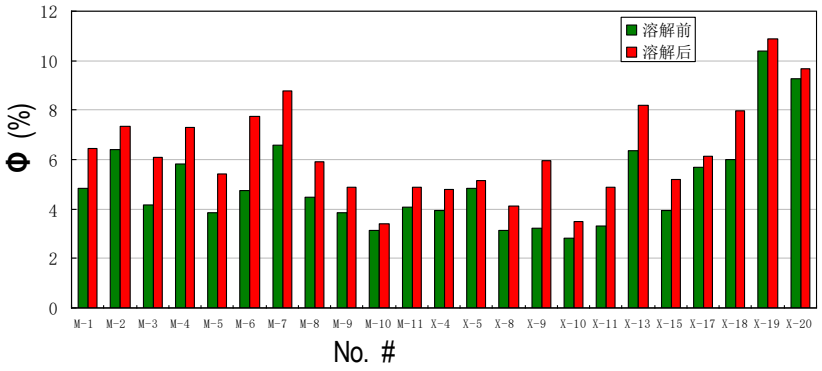
- GuanWuShan Formation is typical of dissolution cave filled with 2 types of asphaltum
- DTC/DTS and Rt increase with the existence of asphaltum

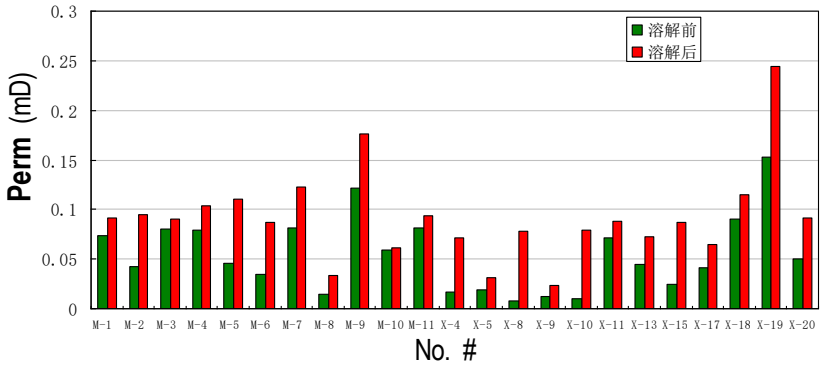


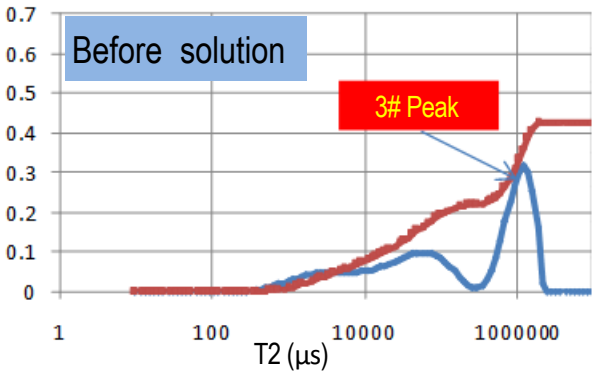


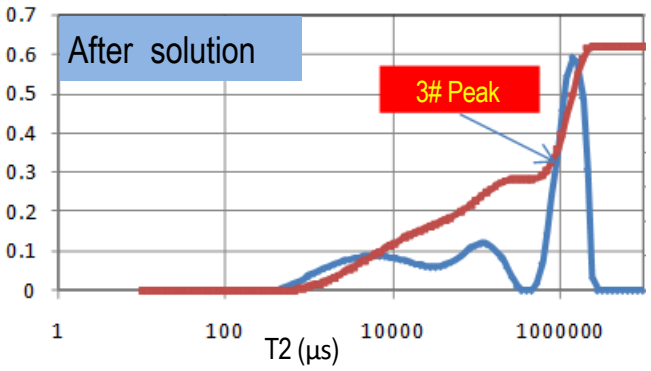


- Φ/K/T2 test before & after solution of asphaltum show that both pore size and connectivity are affected by the asphaltum.
- Φe from T2 may be related to the volume of asphaltum.

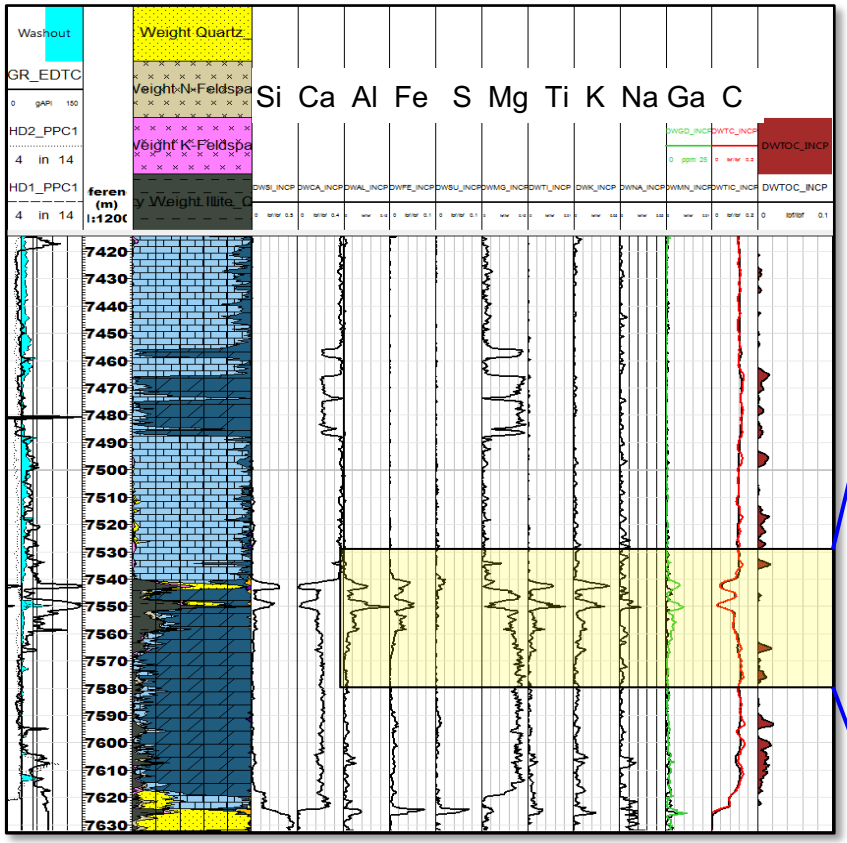


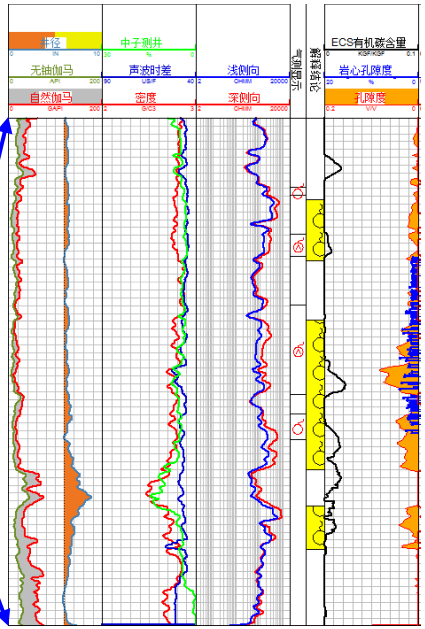


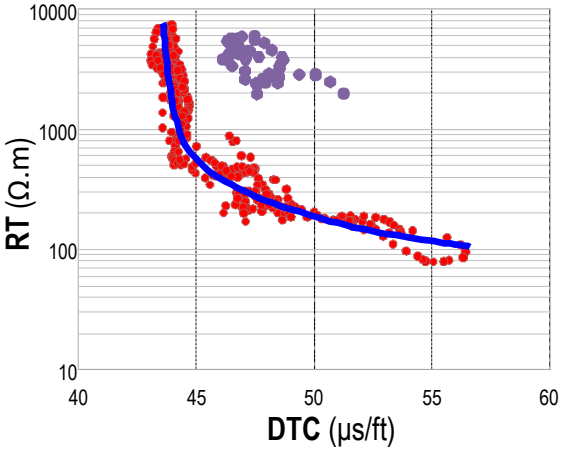


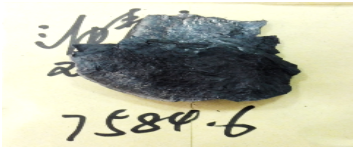


- ϕ_e from conventional logs is too large, and needs correction
- LithoScanner provides accurate volume of asphaltum and make the correction posssible.





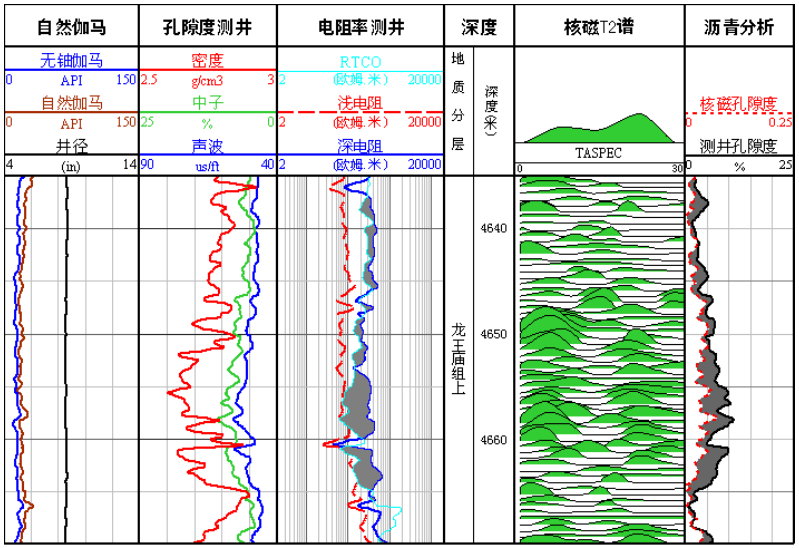


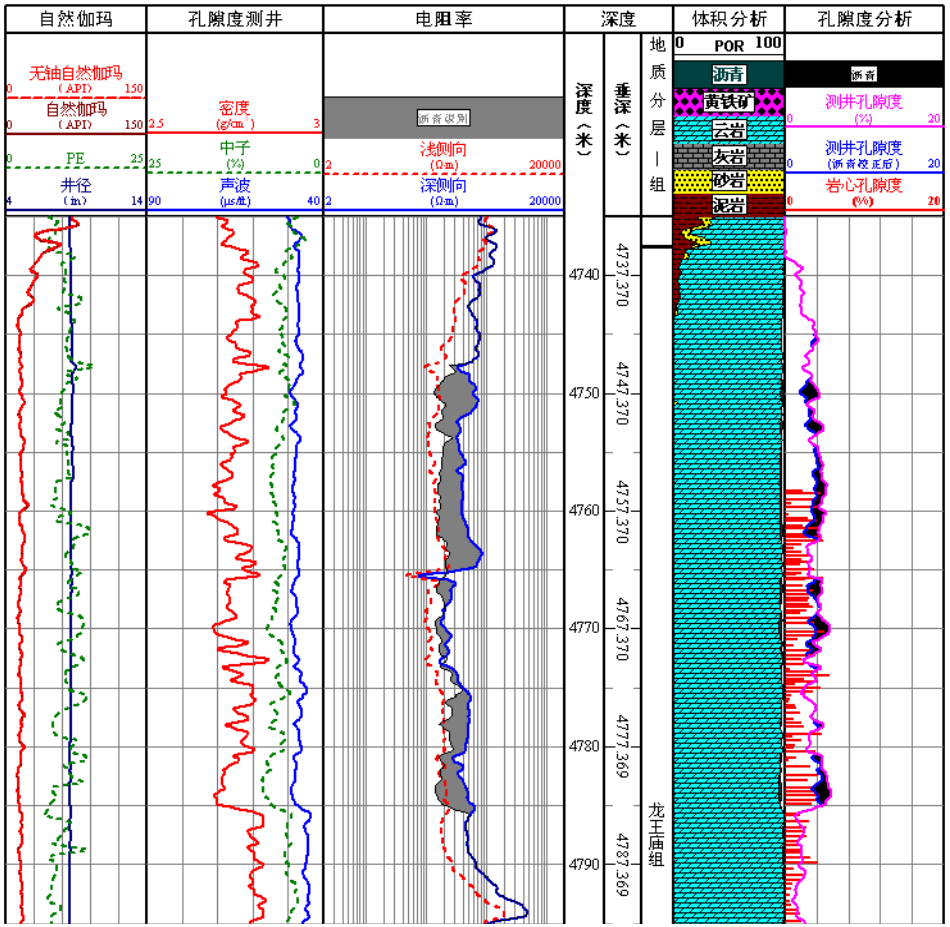


7595.66~7595.78m

- Based on CMR, it is also possible to determine the volume of asphaltum and also the effective porosity.

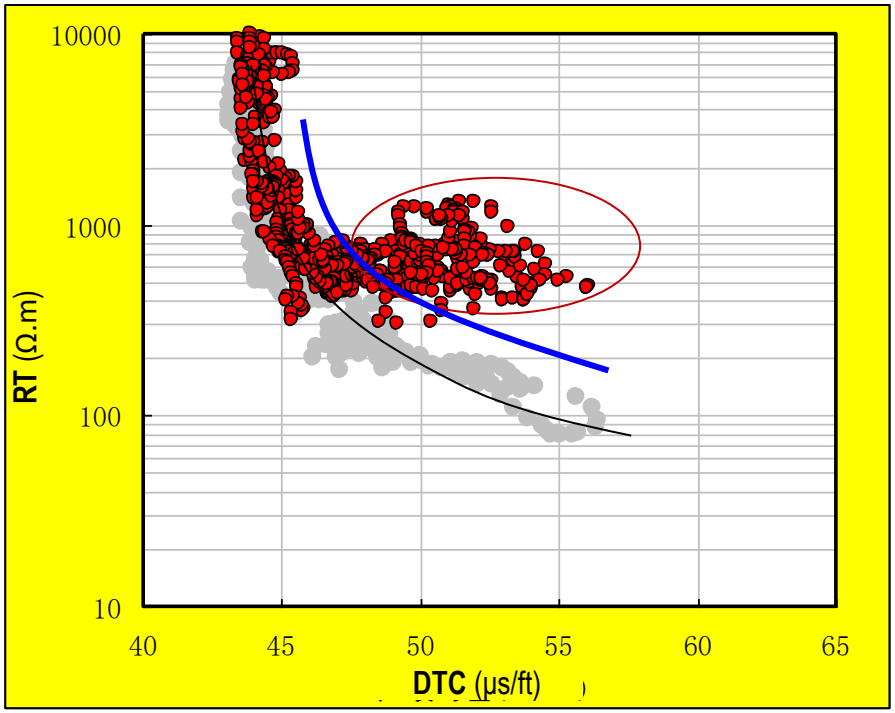
$$VOL_{asph.} = \Phi_{conv.} - \Phi_{eT2}$$

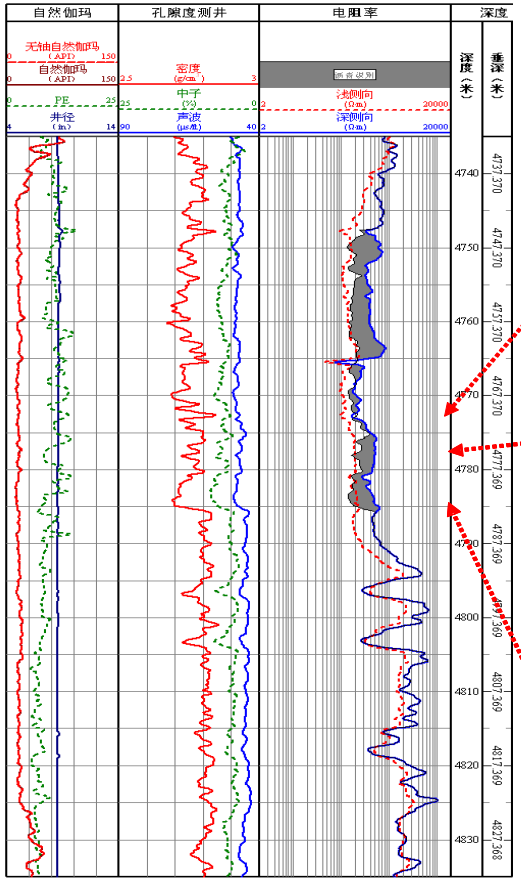


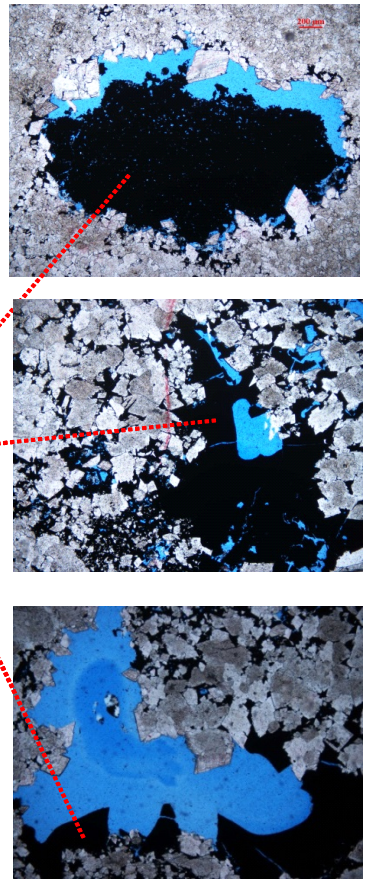


Part Ⅲ. Case of Carbonate Gas Reservoir filled with Asphaltum

- Qualitatively, it is also possible to identify asphaltum zone by conventional logs：
  low GR， AC is reverse to RT







Summary

Reservoir quality in PetroChina's domestic exploration and production area become continuous deterioration, so that need to use advanced well log techniques，which include LithoScanner, CMR-NG and ultra high temperature high pressure wirelog equipment, to deeply evaluate these complex reservoirs.

Thanks