Deep Gas Discoveries and New Exploration Horizons in the Songliao Basin*

By

Zhi-qiang Feng[1], Wei Huang[1], Heyong Wu[1], Jingshun Qi[1] and Changhai Yin[1]

Search and Discovery Article #10148 (2008)
Posted October 24, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, Texas, April 20-23, 2008.

[1] PetroChina Daqing Oilfield Company, Daquing City, China (fengzhiqiang@petrochina.com)

Abstract

The Songliao Basin is a Mesozoic-Cenozoic basin with structures that formed during two stages of development. Rift development in the Late Jurassic to Early Cretaceous period resulted in the deposition of thick clastic and volcanic sediments in isolated rift depressions, with average area around 1300-5800 sq. km, whereas the sag development in the Upper Cretaceous series led to several kilometers of freshwater lacustrine-deltaic sediments in a gigantic sag basin. A number of giant oil discoveries were made by early exploration of structural traps in the Upper Cretaceous strata. The depletion of oil reserves in this basin from over half of a century's production has been substantially offset by oil reserve addition from increased exploration of subtle stratigraphic-lithological traps toward the distal parts of the basin, and more importantly by major breakthroughs in gas exploration in the deep rift depressions underlying the current oil production zones. This presentation will use the giant gas discovery from volcanic reservoirs in the Xujiaweizi rift depression, as an example, to discuss the critical geological controls on volcanic reservoir properties and to highlight the exploration strategies and key technical factors that were responsible for the discovery. The deep discovery in volcanic reservoirs will not only broaden the exploration scope in the Songliao Basin, but also provide an excellent analog for exploration in other rift basins worldwide.

中国石油大庆油田公司

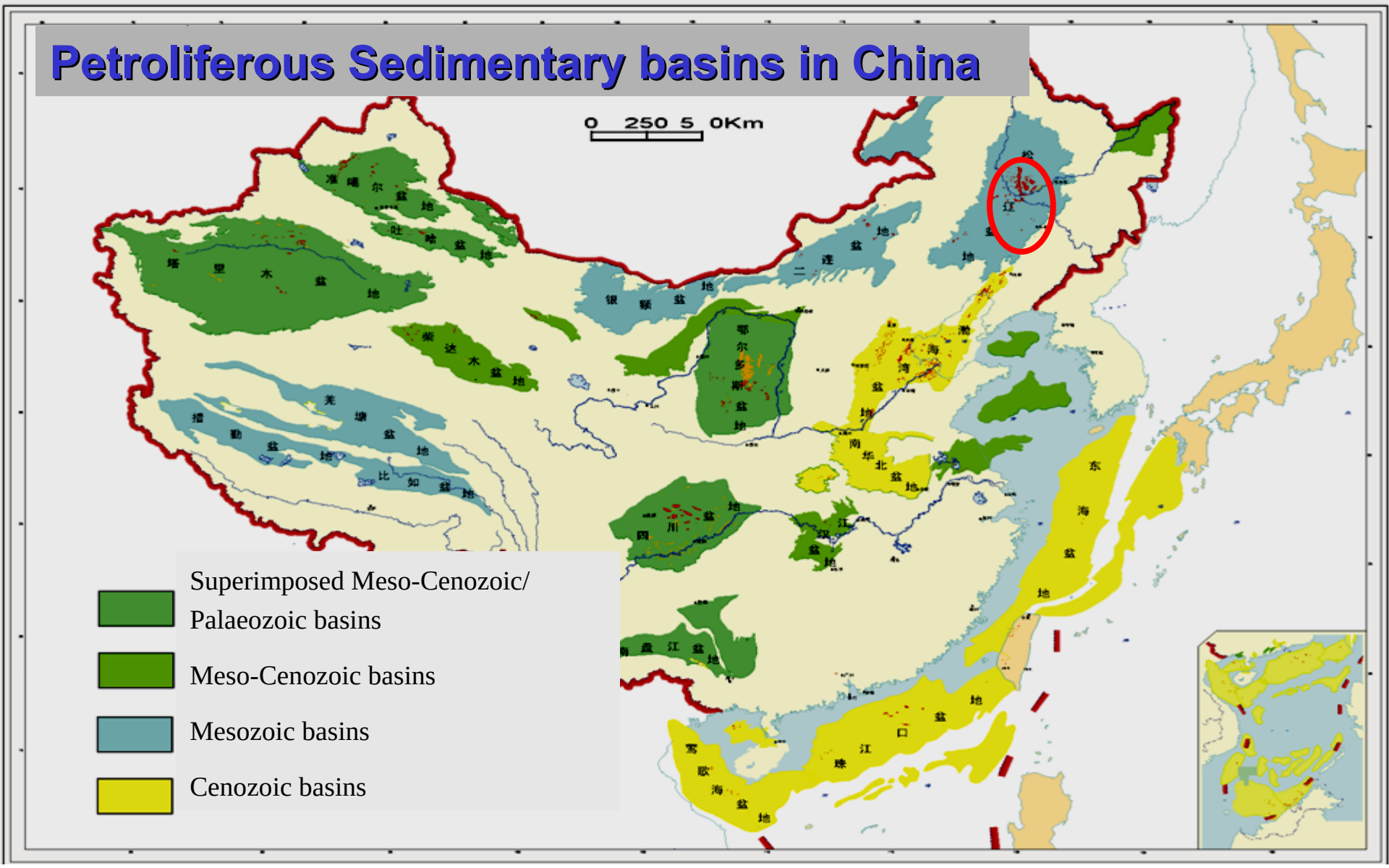
Deep Gas Discoveries and New Exploration Horizons in the Songliao Basin, NE China

Feng Zhi-qiang

PetroChina Daqing Oilfield Company Ltd.

April 23, 2008

Petroliferous Sedimentary basins in China



Songliao Basin, with an area of 260,000 km^2, home of the largest non-marine oil field in China, leads the China in giant gas discoveries from volcanic reservoirs

Outline

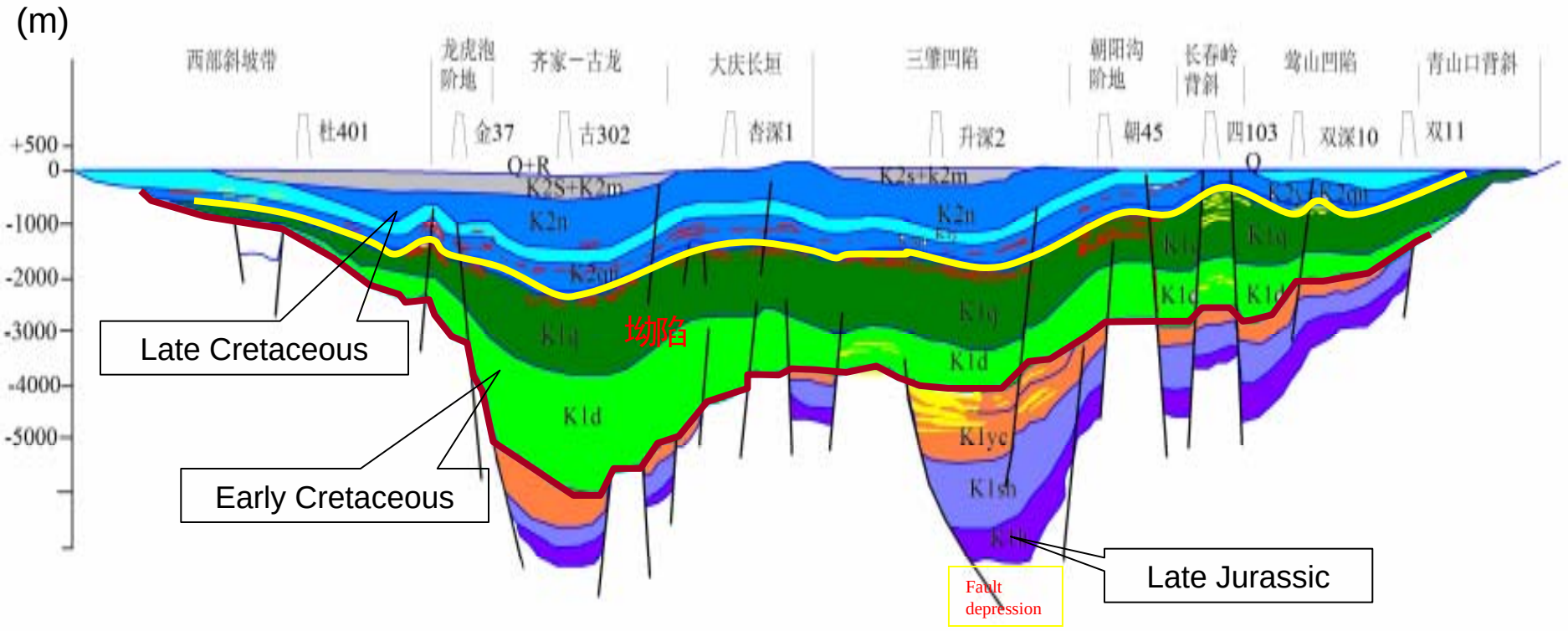
I. Geological setting

II. Characteristics of volcanic reservoir

III. Implications for further exploration

IV. Key exploration technology

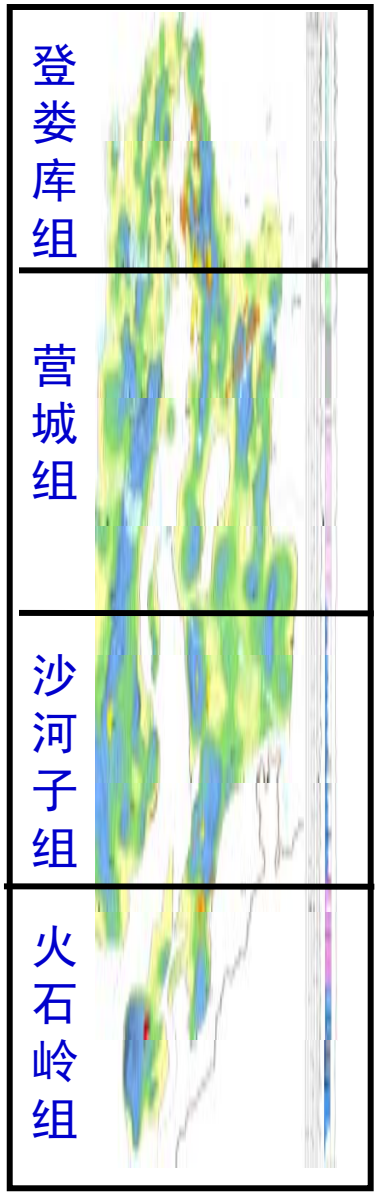
Dual structure of the basin fill



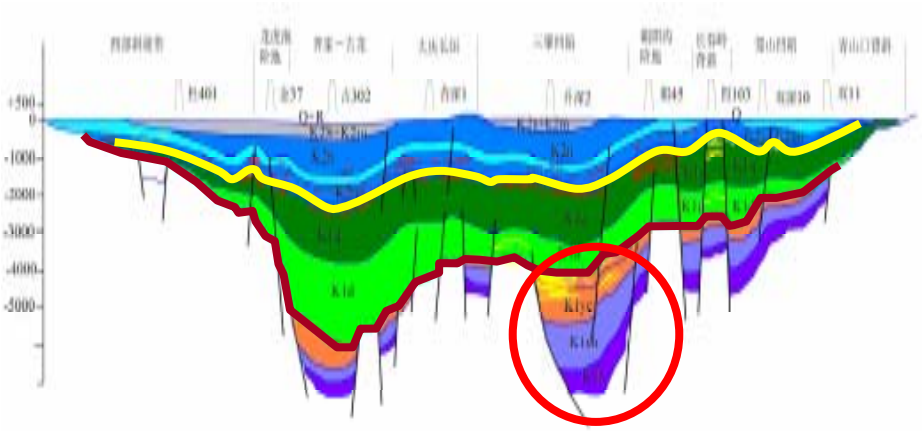
Upper Cretaceous: sag clastic sediments (oil habitat)

Lower Cretaceous: rift volcanigenic succession (gas habitat)

Stratigraphy of rift sediments



Seal （k1 – d)

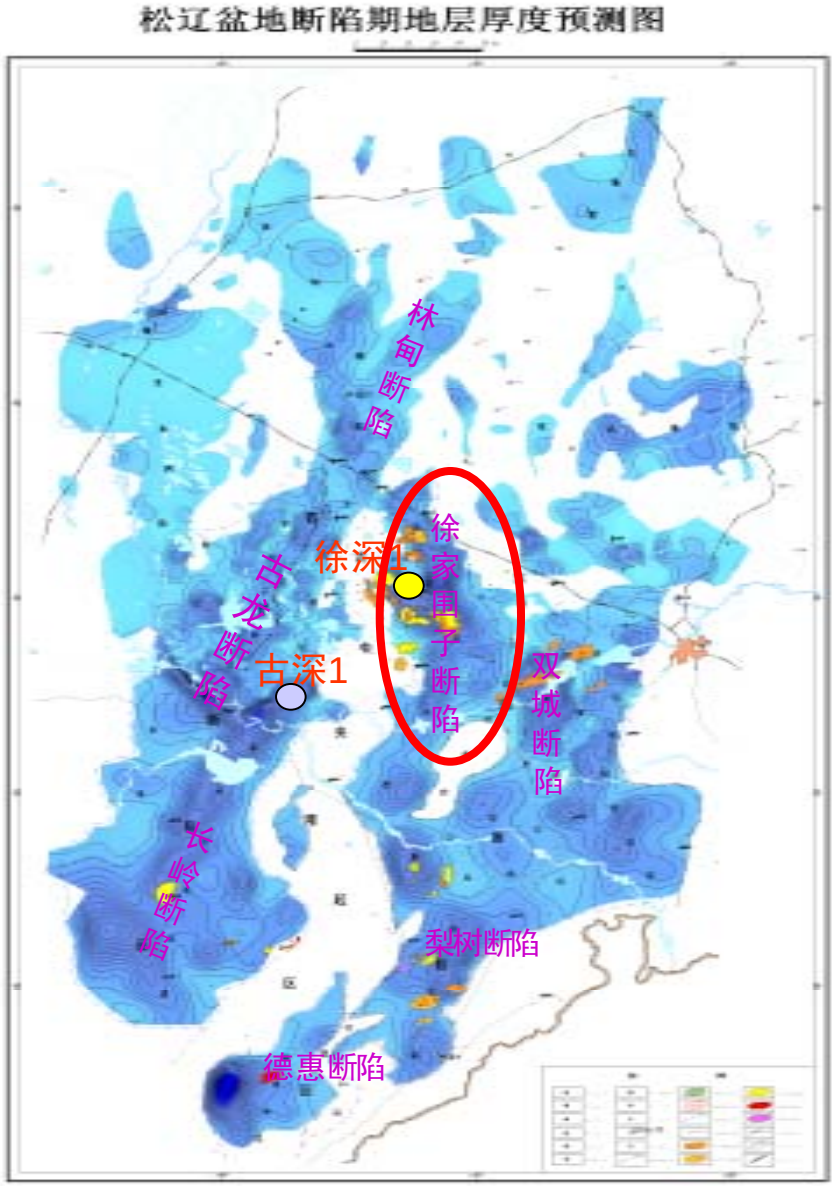


Volcanic Reservoirs （K1- Yc）

Source Rocks （K1-Sh）

Source Rocks （J3 - h）

Distribution of faulted depressions



Lower Cretaceous Contour Map

- Over 30 grabens identified
- Total potential exploration area of 50,000 km^2

Outline

I. Geological setting

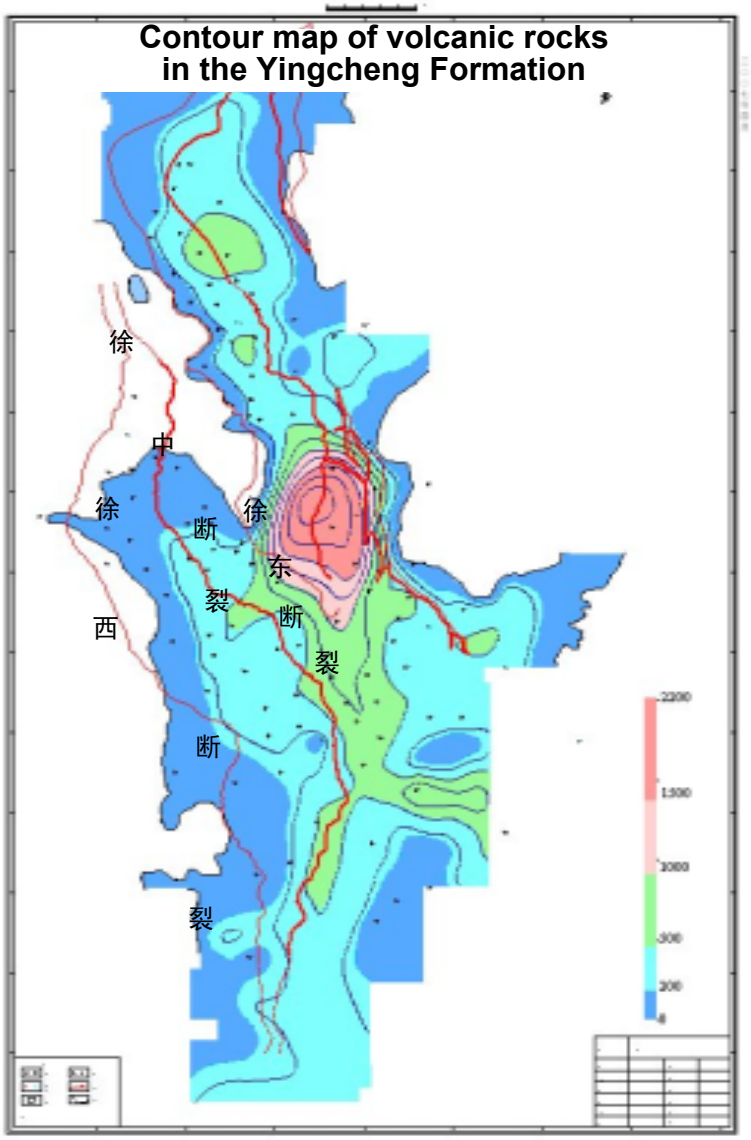
II. Characteristics of volcanic reservoir

III. Implications for further exploration

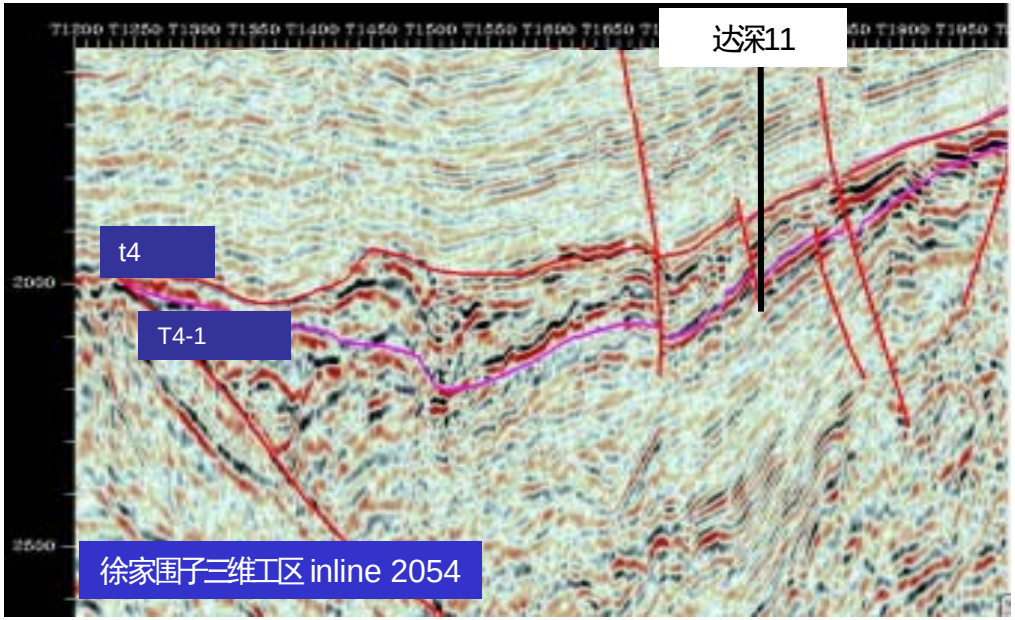
IV. Key exploration technology

Volcanic rock distribution

in the Xijiaweizi Depression



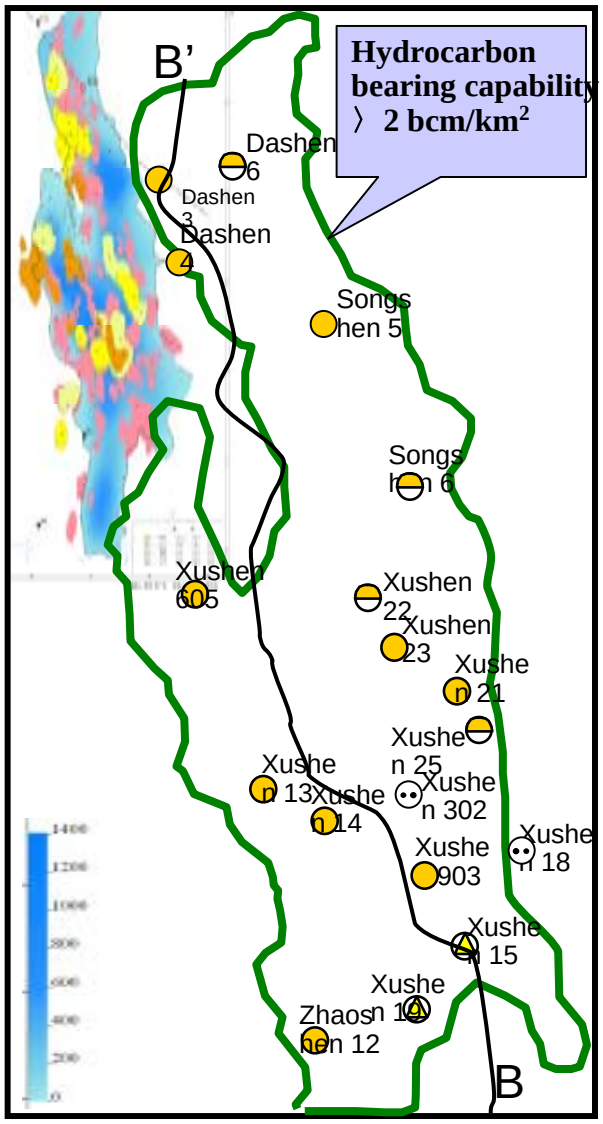
- **Depression size: 5000 km²**
- **Volcanic area: 3500 km²**
- **Av.thickness: 200-1000 m**
- **Max thickness: 2200 m**



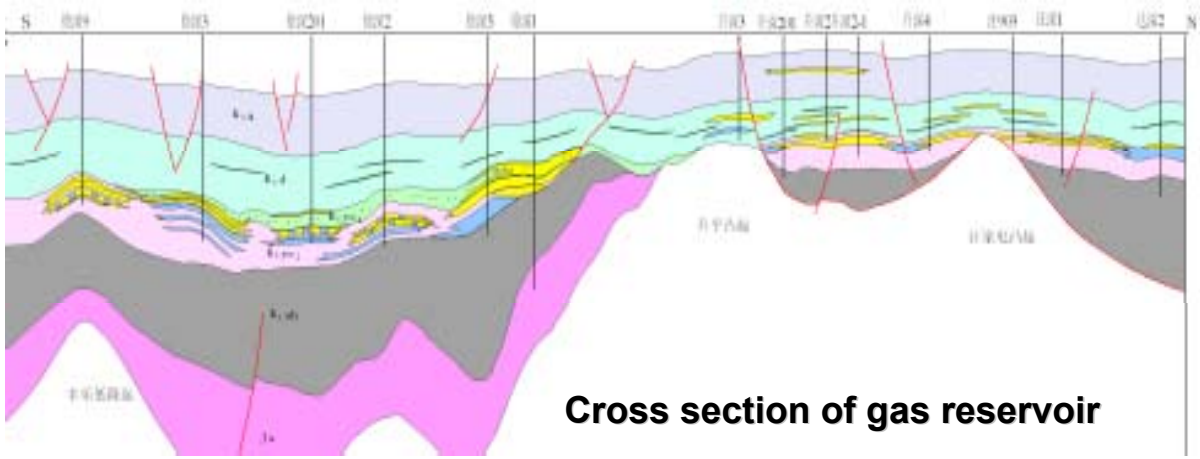
Exploration wells: 50

3D-seismic data obtained: 5000 km²

Volcanic rock gas pools occur mainly in structural-lithologic traps



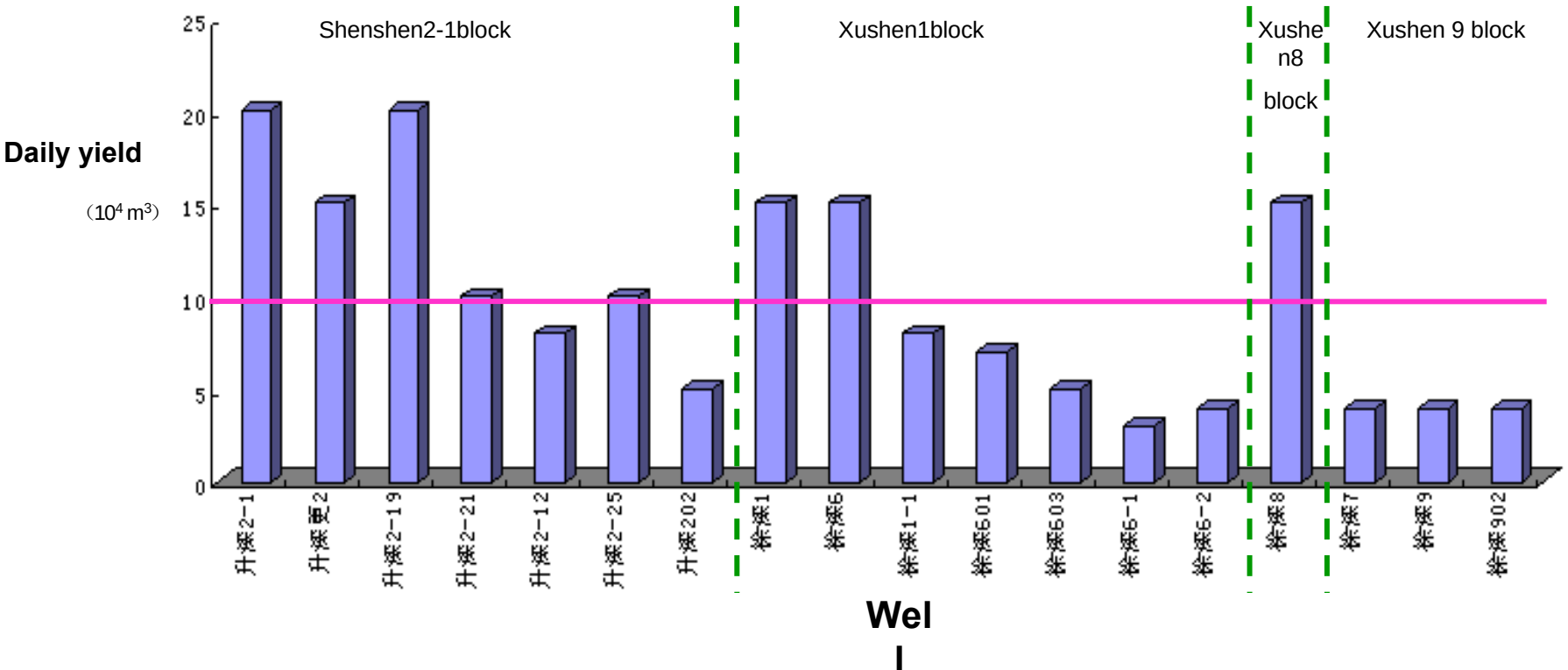
- Strong reservoir hetereogeneities both laterally and vertically stacked reserviors, without uniform gas-water contact
- Gas show is widespread in strata overlying the source rocks
- Thick gas column at structural highs; commercial flows also obtained at structural lows



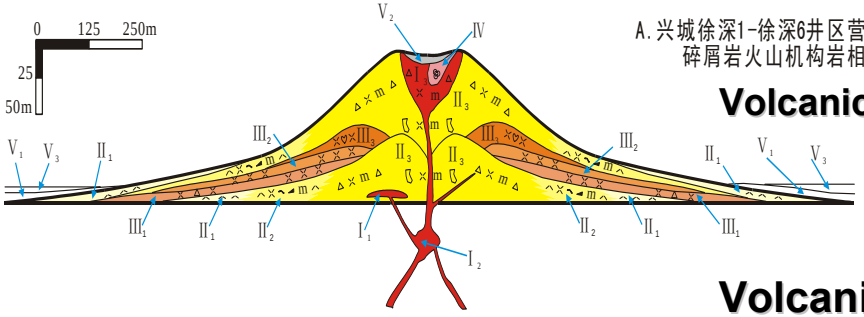
Well testing results

For 18 wells with production test (15 from volcanic and 3 conglomerate):

- **av.daily gas rate: 95,000 m^3**
- **with relative stable pressure**

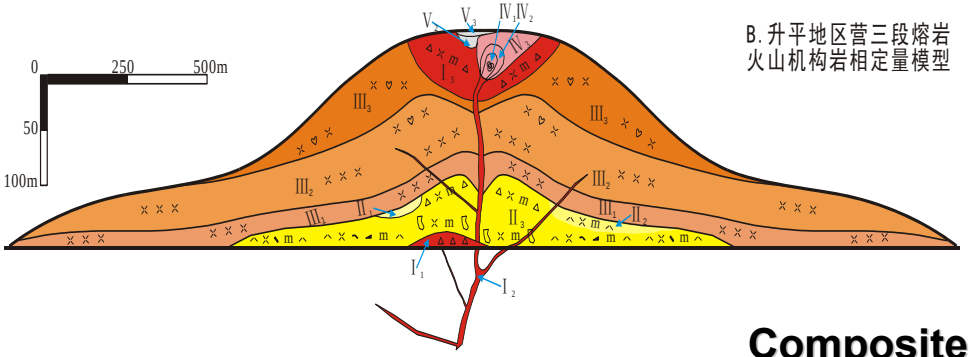


Types of volcanic build up



A. 兴城徐深1-徐深6井区营城组一段
碎屑岩火山机构岩相定量模型

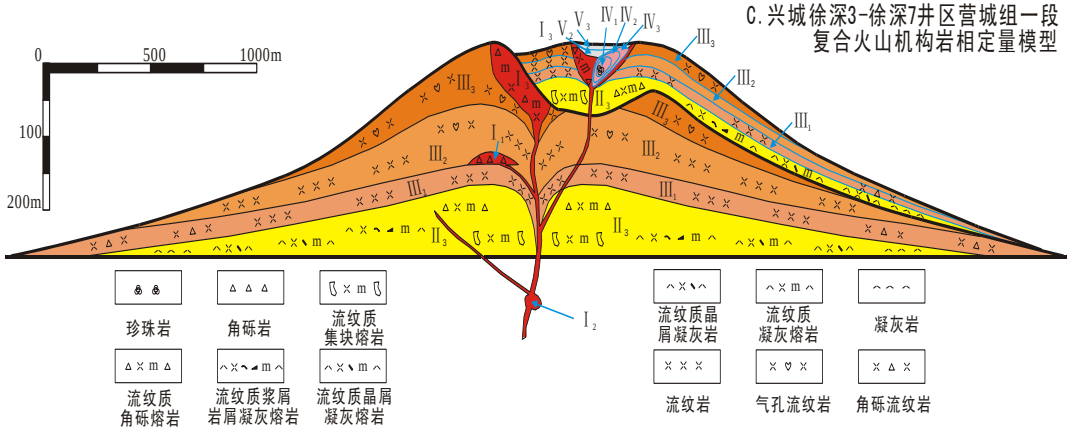
Volcanic edifice (pyroclatics)



B. 升平地区营三段熔岩
火山机构岩相定量模型

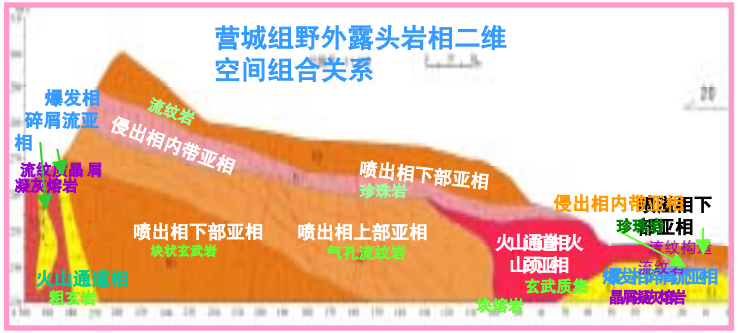
Volcanic edifice (lava)

Composite volcanic edifice



C. 兴城徐深3-徐深7井区营城组一段
复合火山机构岩相定量模型

Outcrop exposure



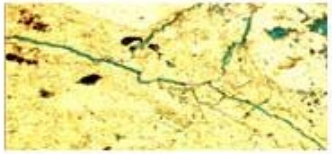
Volcanic reservoir pore space types

原生孔隙

Primary porosity

砾间缝

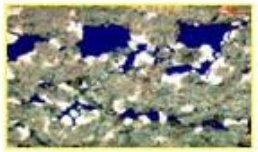
炸裂缝



微裂缝

集块岩　砾间孔

晶粒间孔



流纹岩气孔

基质内微孔

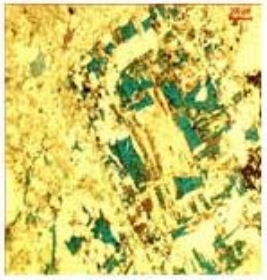
次生孔隙

Secondary porosity

高角度构造裂缝

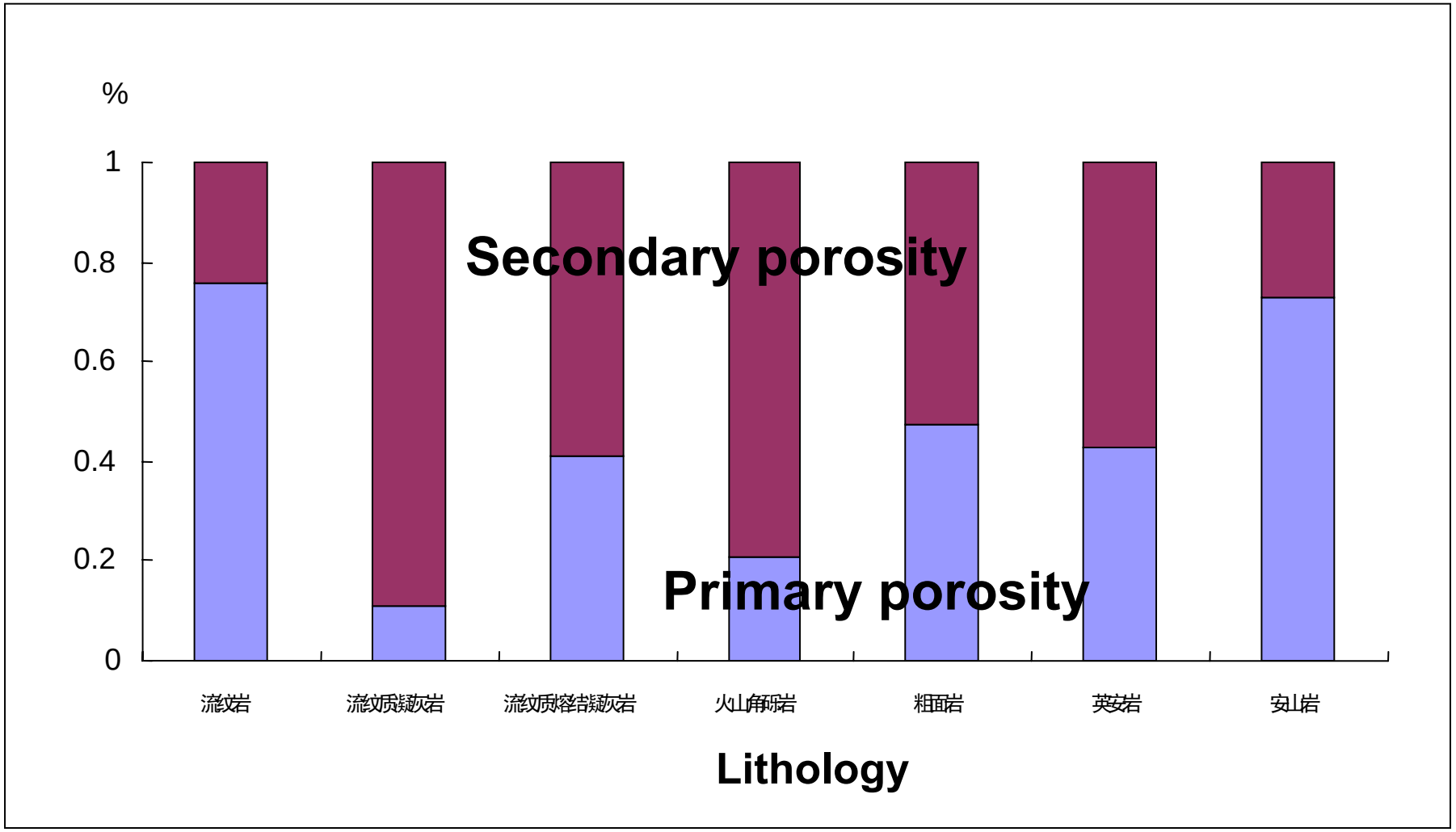
水平构造裂缝

溶蚀裂缝



长石斑晶与基质溶孔发育

Secondary porosity is important for tuff reservoir



Evaluation criteria for deep volcanic reservoirs in the Songliao Basin

Reservoir type	Porosity (%)	Permeability (mD)	Well Results
Ⅰ. Good reservoir	≥10	≥1	Xushen 8 well 11.6% porosity 22,0000 m^3
Ⅱ. Moderate reservoir	6 - 10	0.1 – 1	Xushen 1-1 well 8.2% porosity 446,000 m^3 after fracturing
Ⅲ. Unsatisfactory reservoir	4 – 6	0.05 – 0.1	Xushen 5 well 5.8% porosity 120,000m^3 after fracturing
Ⅳ. Poor reservoir	2 - 4	0.001 – 0.05	Shengshen 5 well 3.8% porosity 108 m^3
Ⅴ. Non-reservoir	<2	<0.001	Fangshen 901 well very low porosity dry

Outline

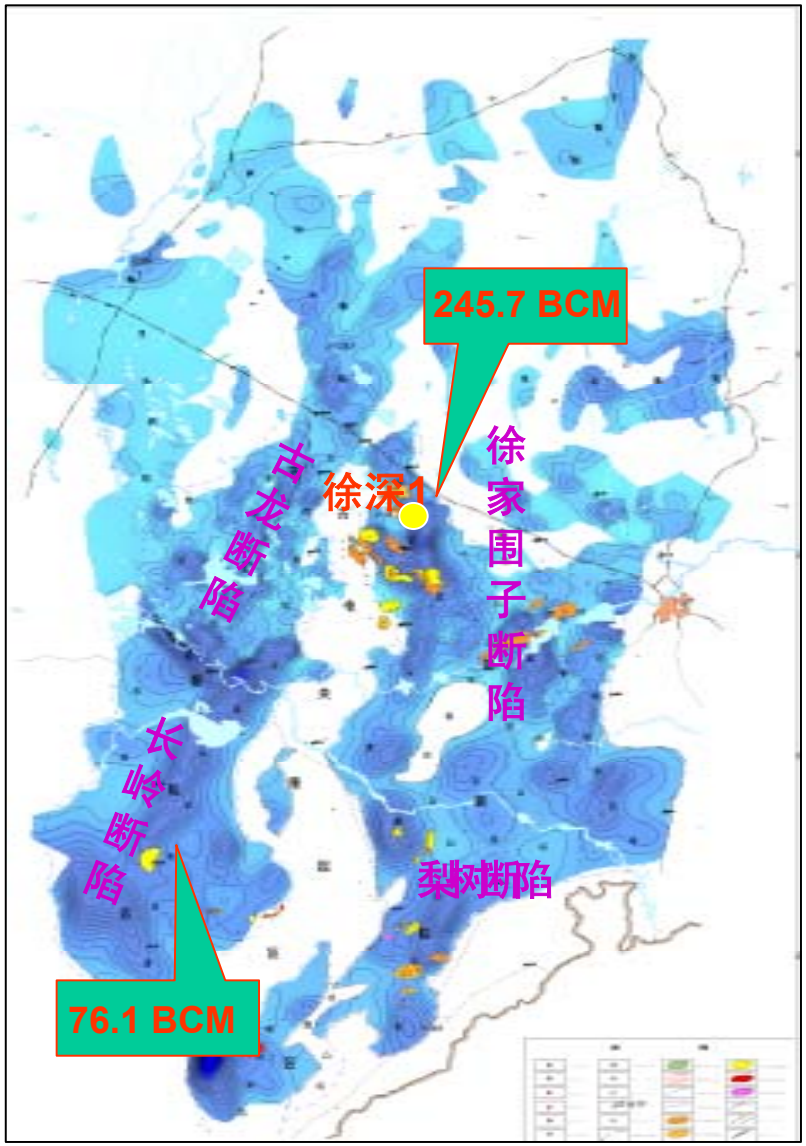
I. Geological setting

II. Characteristics of volcanic reservoir

III. Implications for further exploration

IV. Key exploration technology

Proven gas reserves & exploration potential



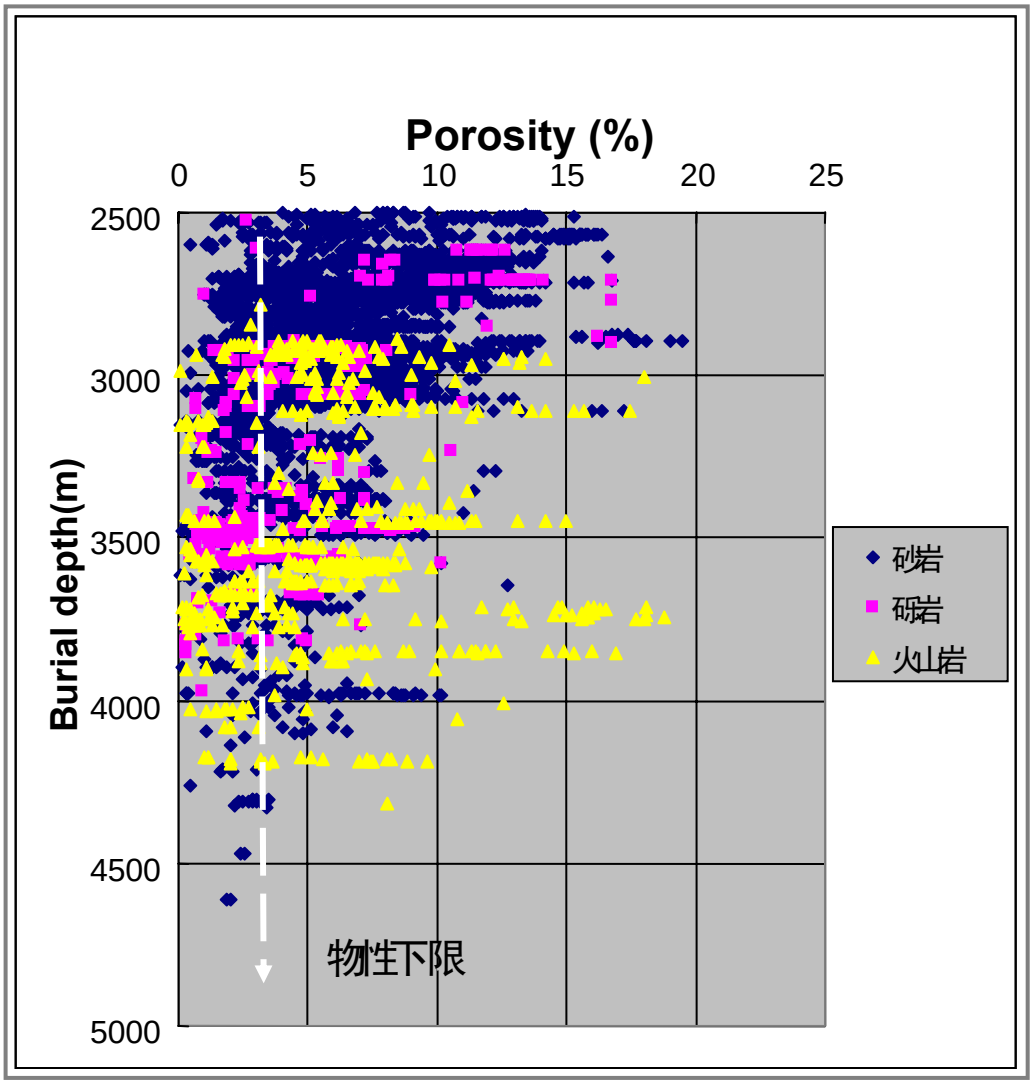
- Proven gas reserves: 10 tcf
- Potential gas: 30 tcf

Implications for further explorations

Deep volcanic reservoirs as important targets due to:

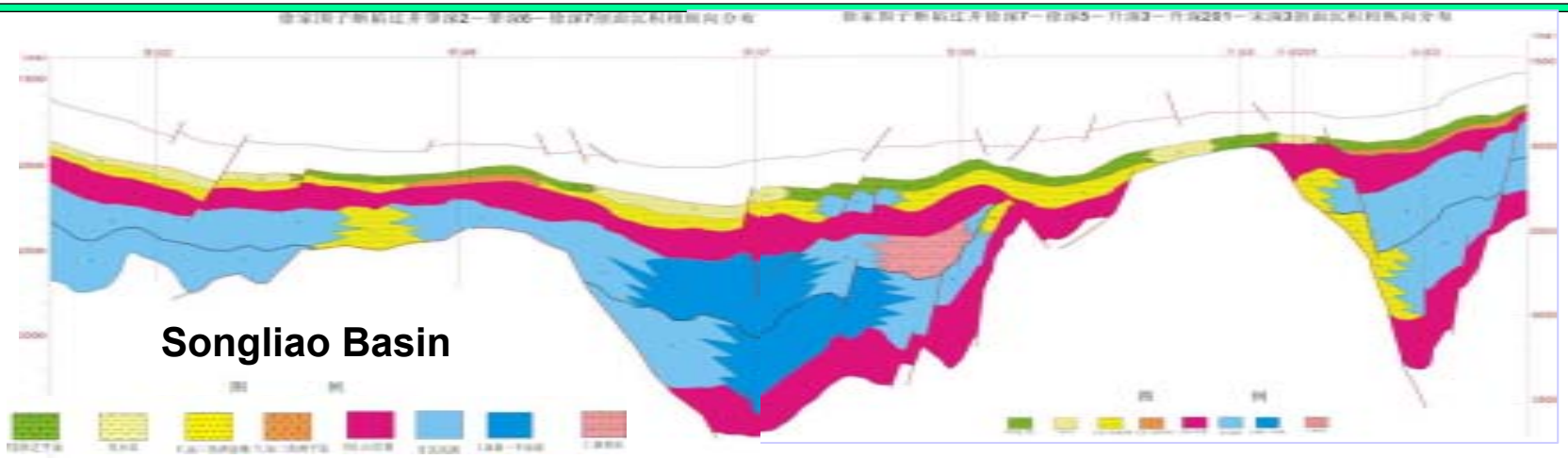
- **Relative good reservoir quality**
- **Large volcanic rock volume**
- **Favorable source-reservoir-seal combinations**

Higher reservoir porosity than clastic rocks in deep strata

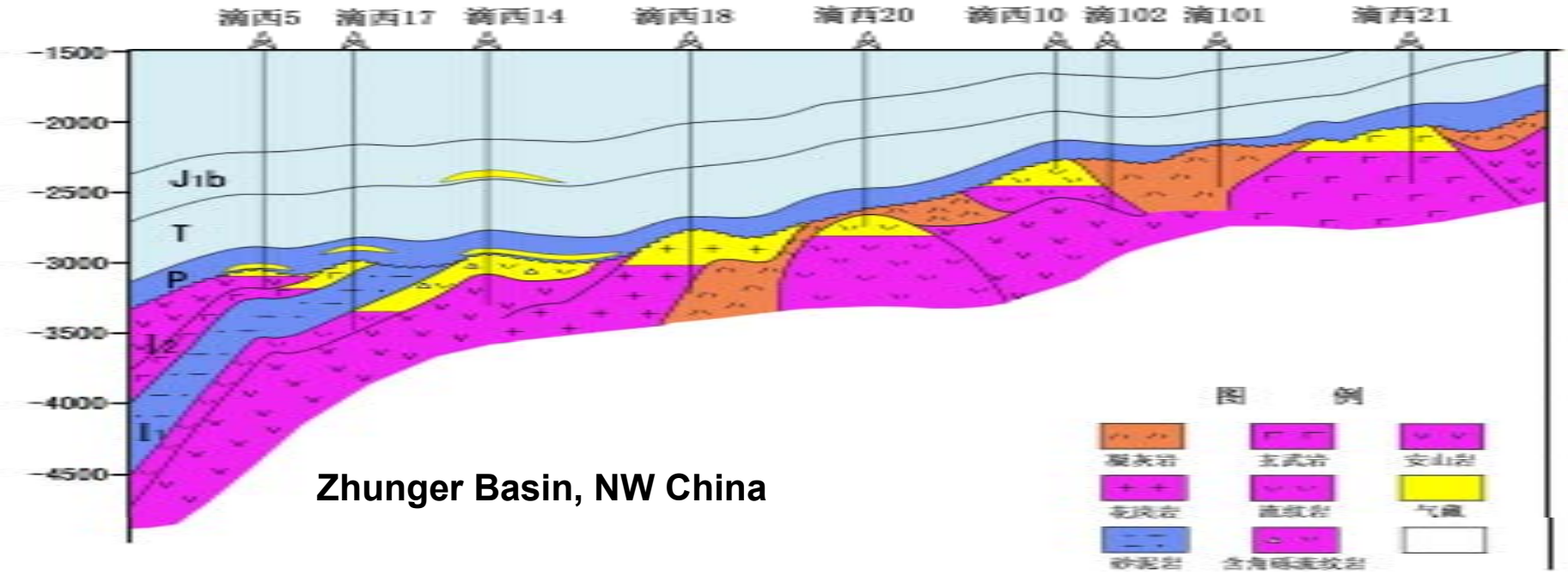


Sandstone
Conglomerate
Volcanic rock

Potential large reservoir volume in deep stata



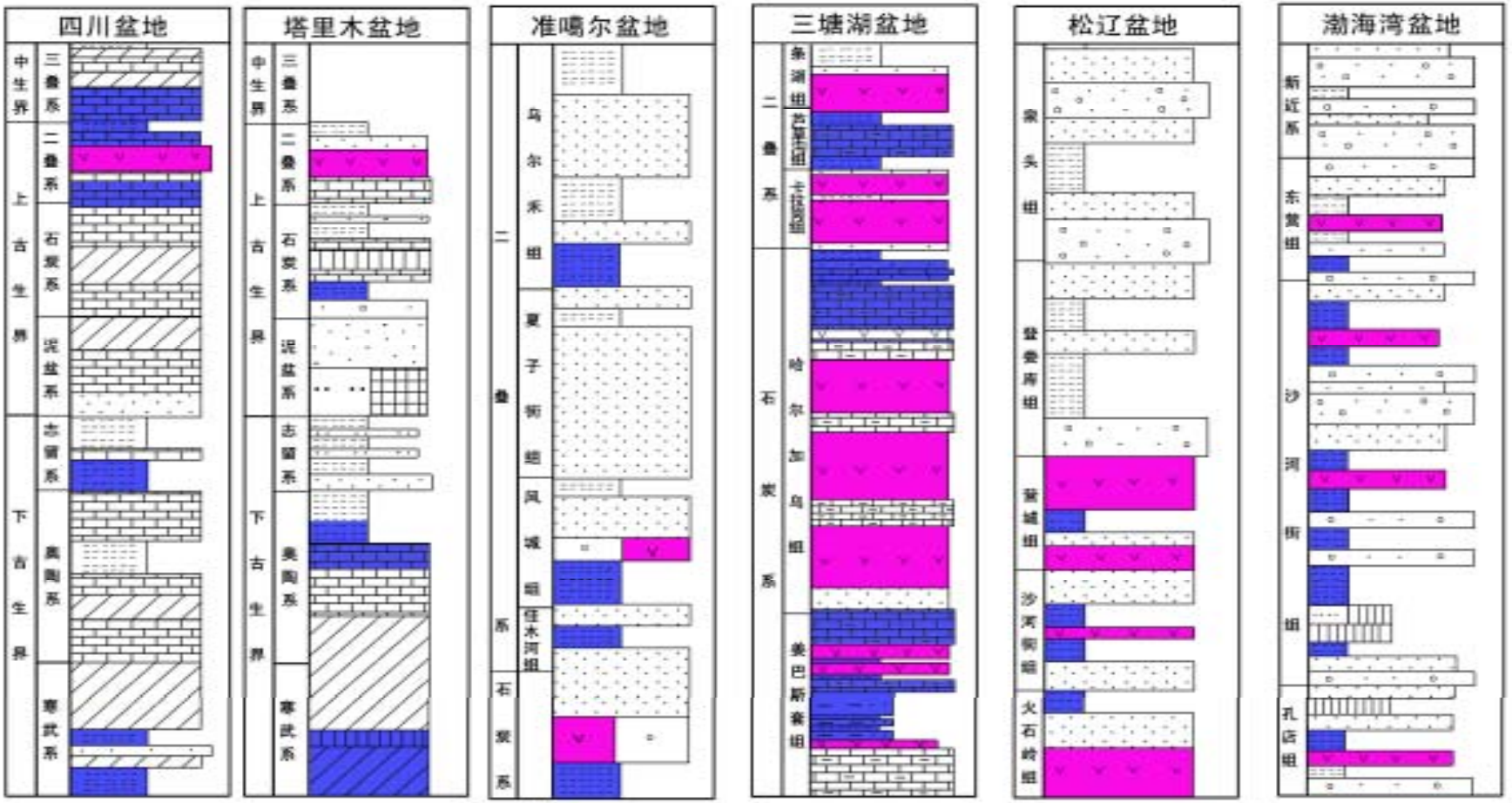
Songliao Basin



Zhunger Basin, NW China

Favorable source-reservoir-seal combinations

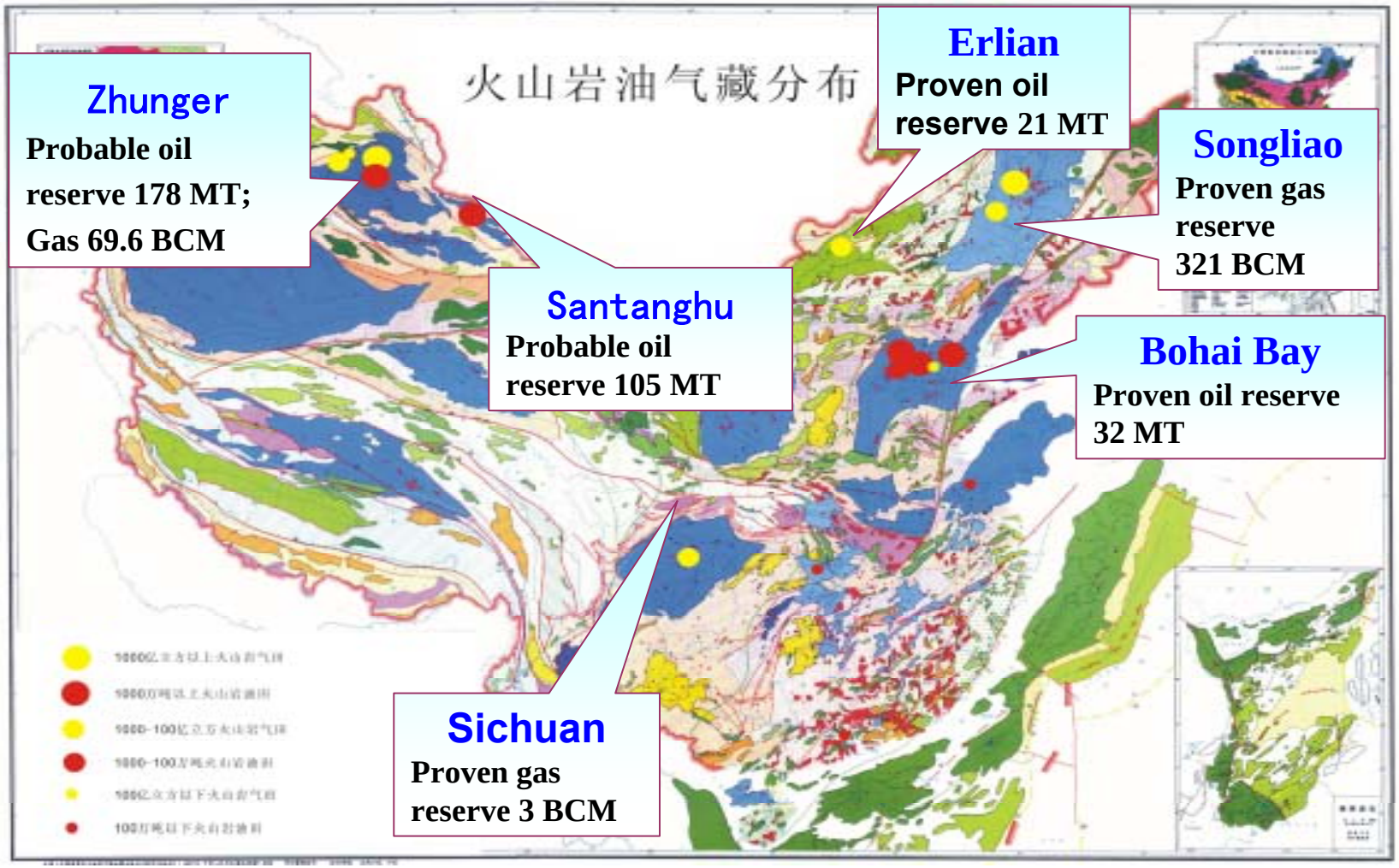
Sichuan | Tarim | Zhunger | Santanghu | Songliao | Bohai Bay



Source rock

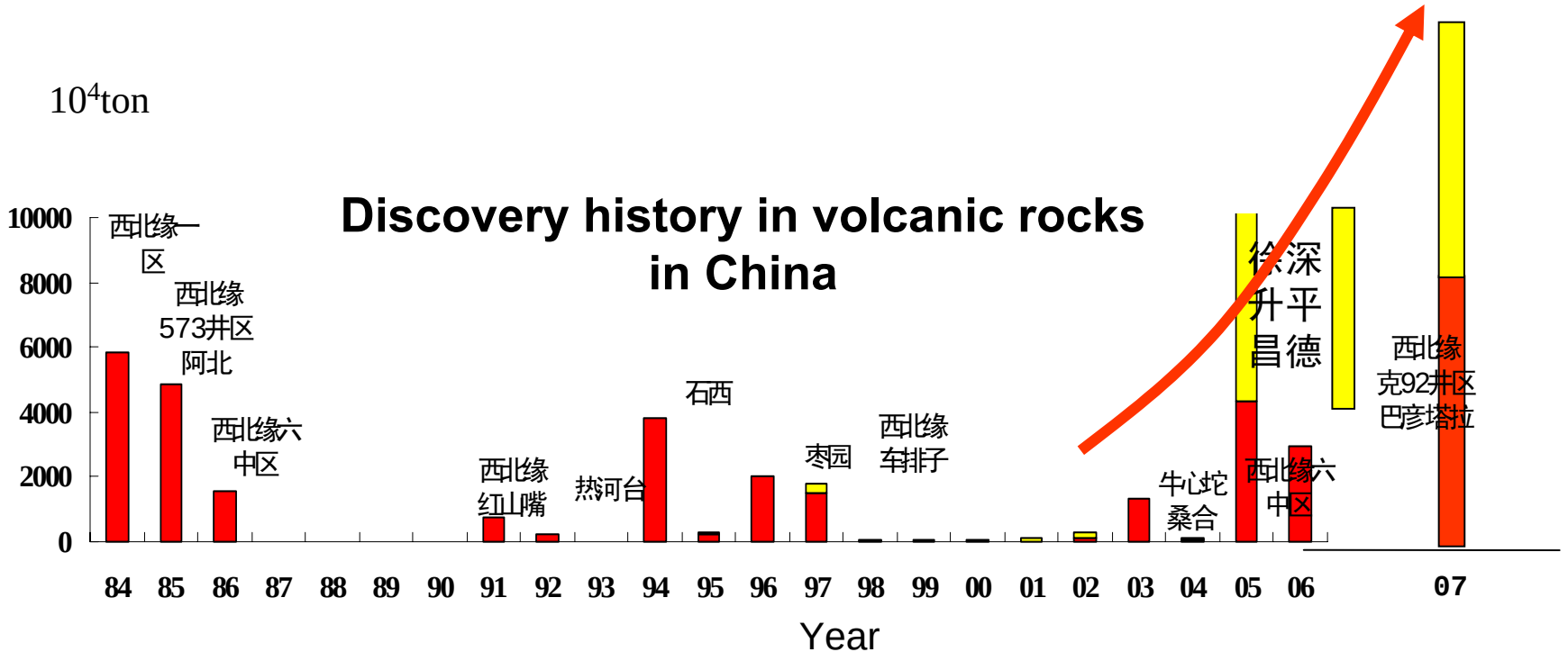
Volcanic reservoir

Major discoveries in deep volcanic reservoirs in China since 2002



Major discoveries in deep volcanic reservoirs in China since 2002

National reserve growth: oil 370 MT，gas 390 BCM



Outline

I. Geological setting

II. Characteristics of volcanic reservoir

III. Implications for further exploration

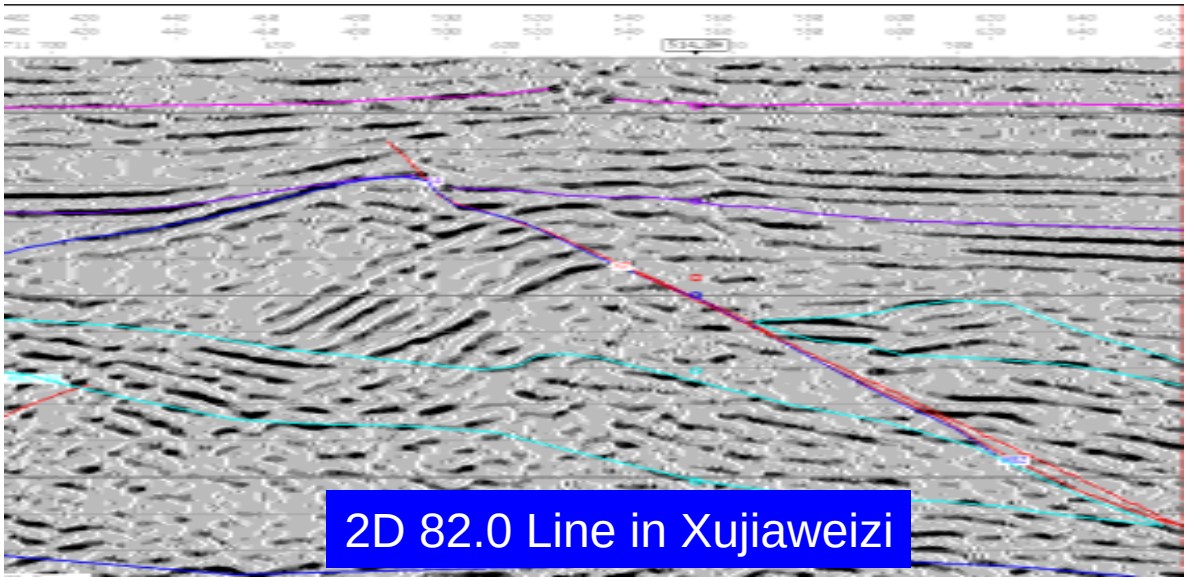
IV. Key exploration technology

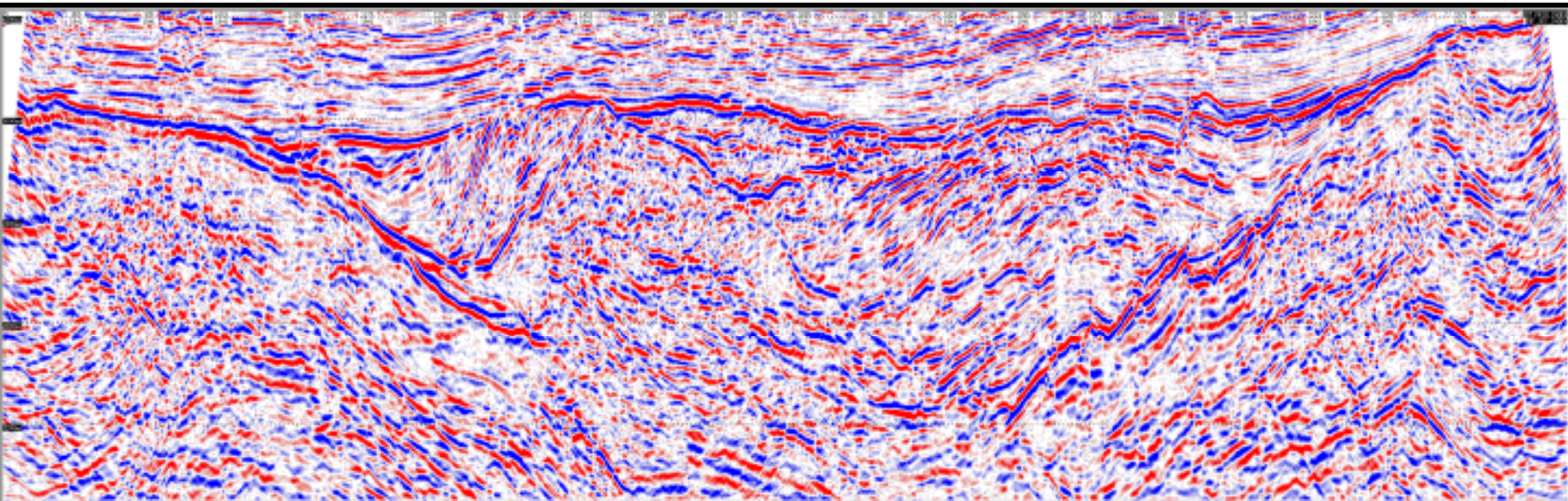
Advanced technologies help exploration in deep volcanic rocks

- **Seismic**
- **Wireline logging**
- **Advanced drilling**
- **Advanced stimulating**

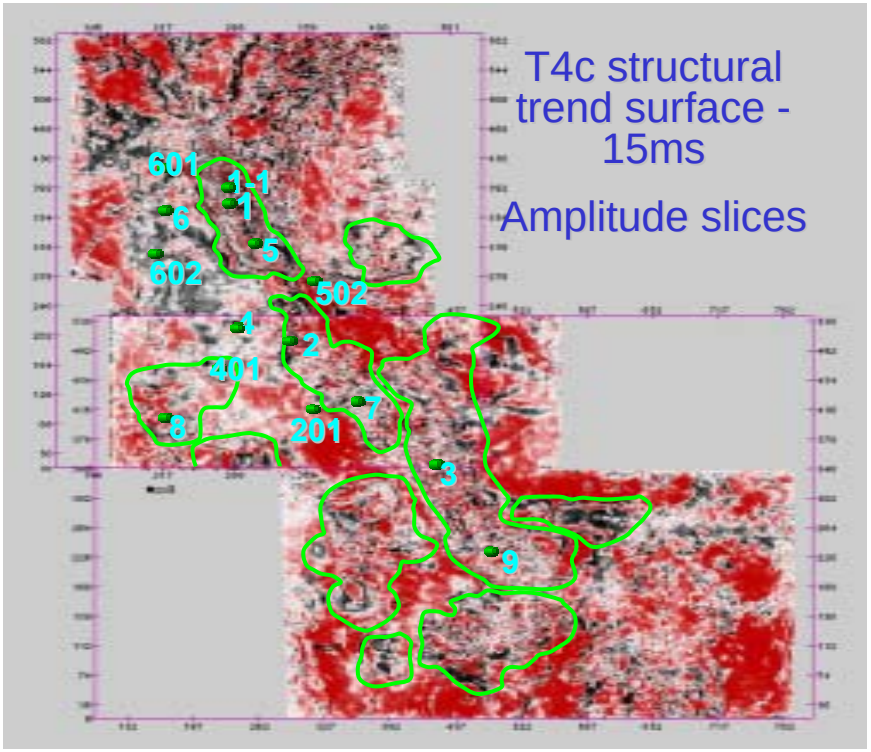
Improved depth imaging

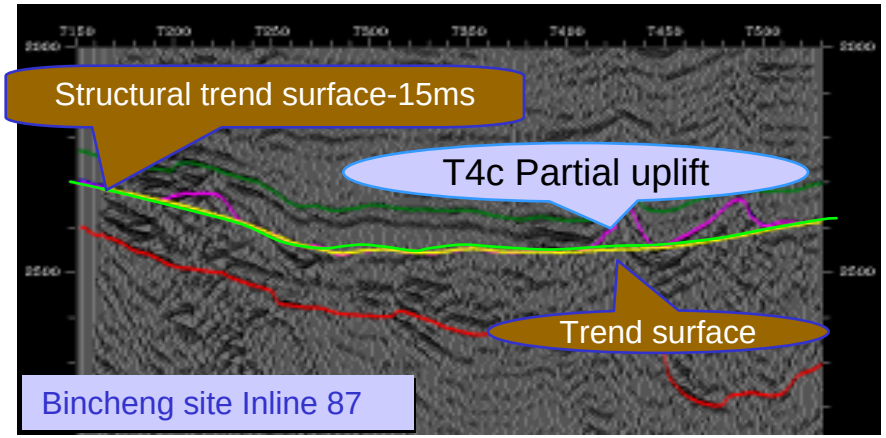
Advanced seismic technologies enhance data quality and make drilling targets clearer

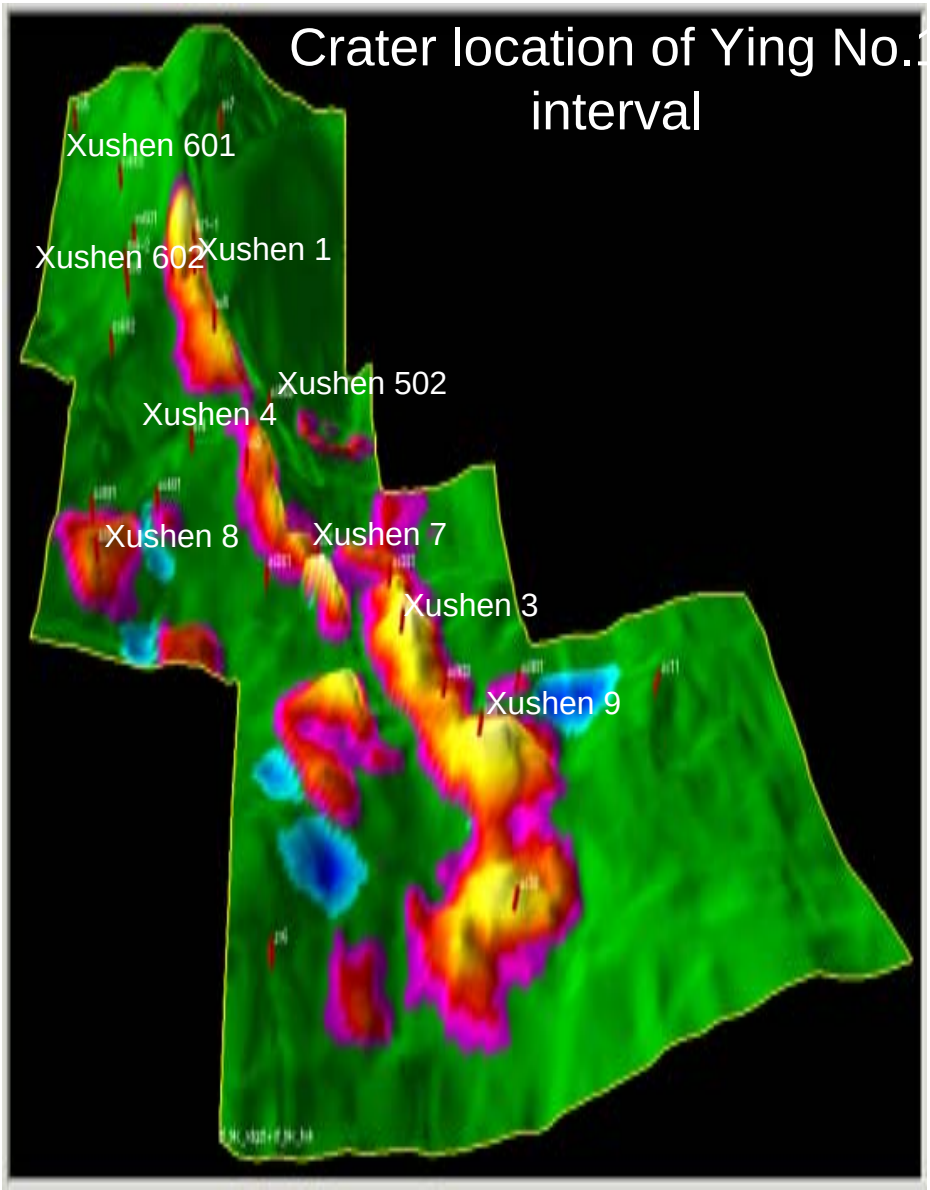




Volcanic reservoir prediction

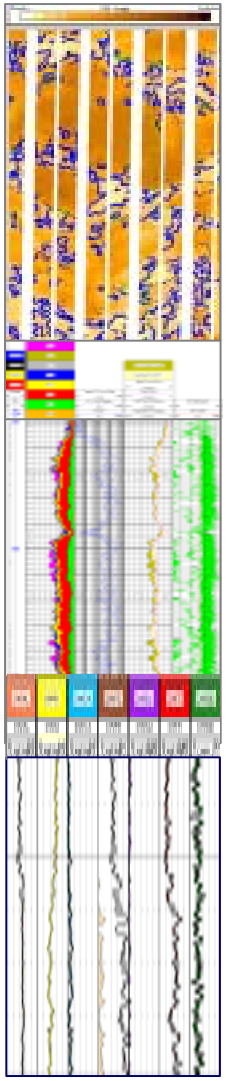






Identify volcanic lithology

Input logging data



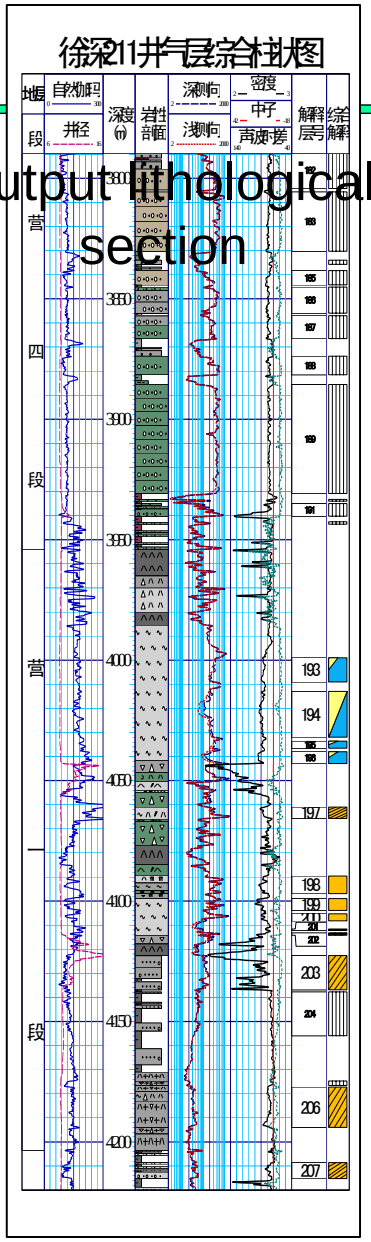
Structural curves of rock
（Imaging logging）

Structural curves of pores
（NML logging）

Component curves of rock
（Element logging）

Neural network method

Output lithological section



More accurate porosity estimation

Much better coordination between calculated porosity and core analysis results

Calculating flow of porosity

Element component of the reservoir by ECS logging

↓

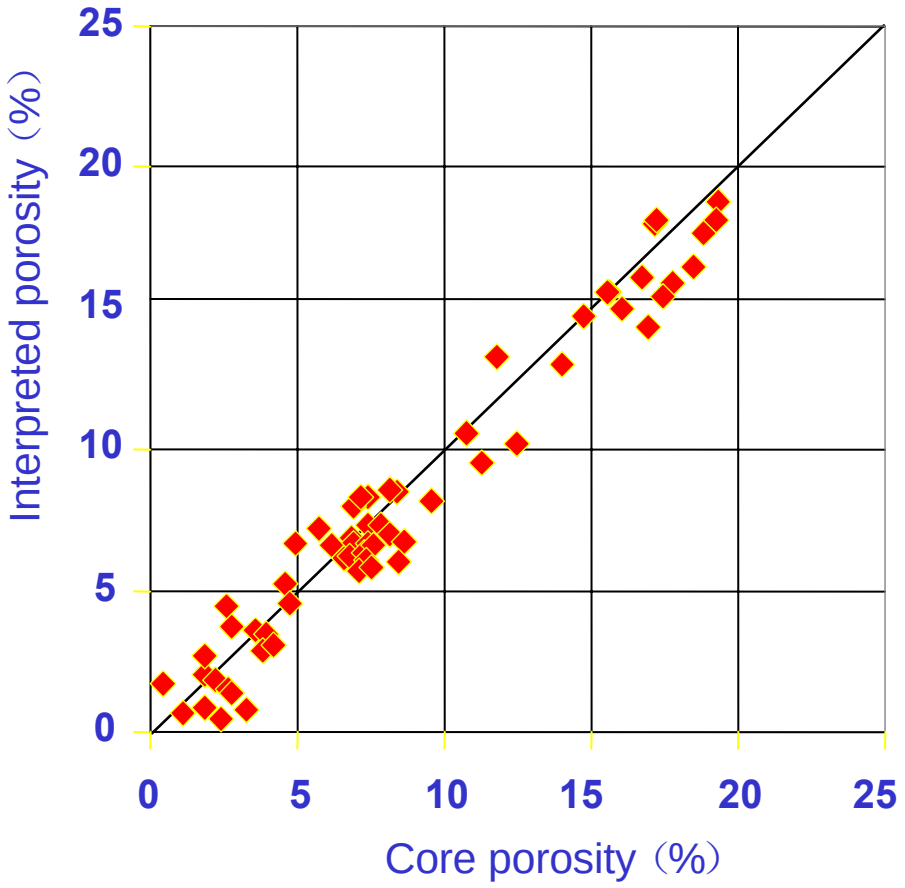
Establish relationship between element component and framework parameters

↓

ECS calculated porosity + NML porosity

↓

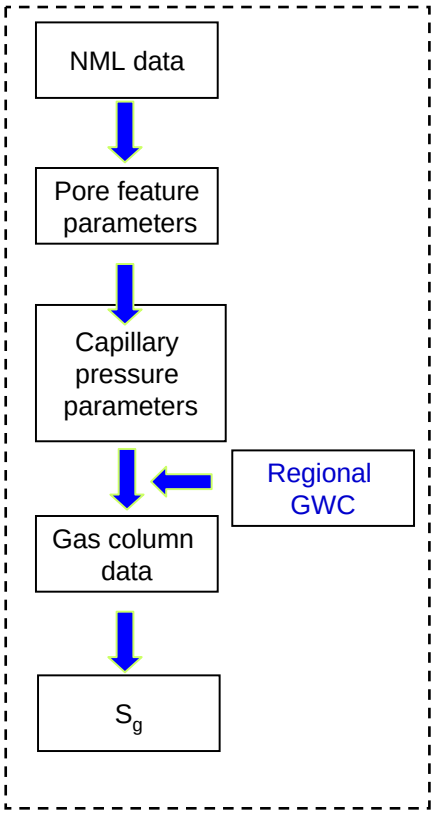
Formation porosity



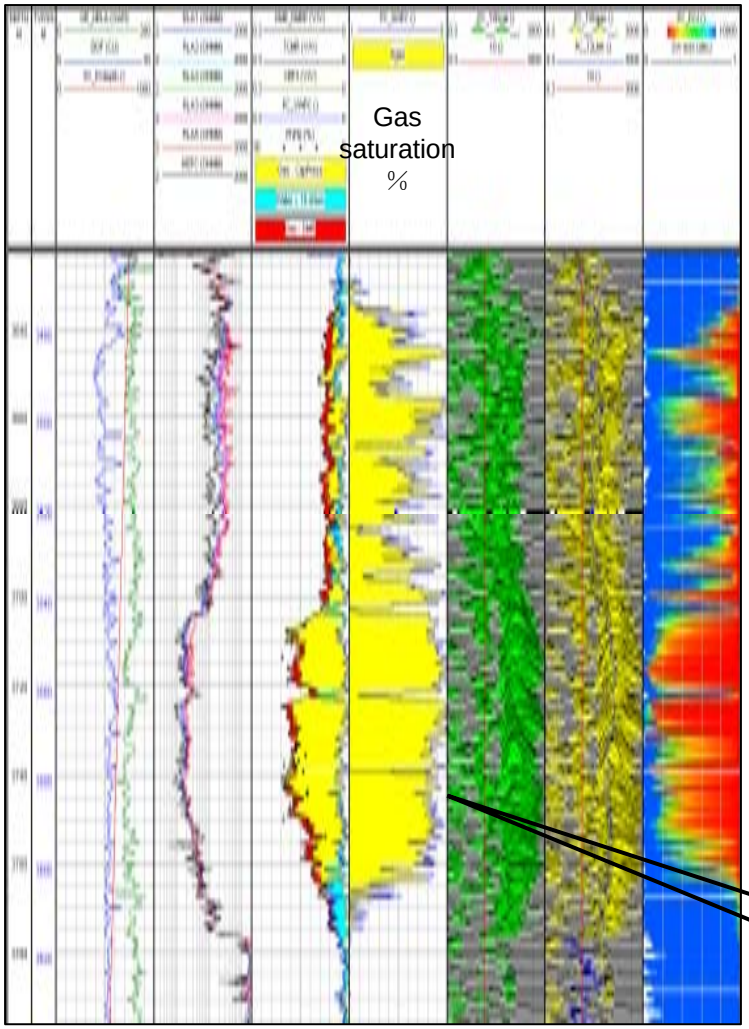
Even absolute error：1.0%

Gas saturation estimation

S_g calculating flow



Interpreted results of Xushen 8 well logs

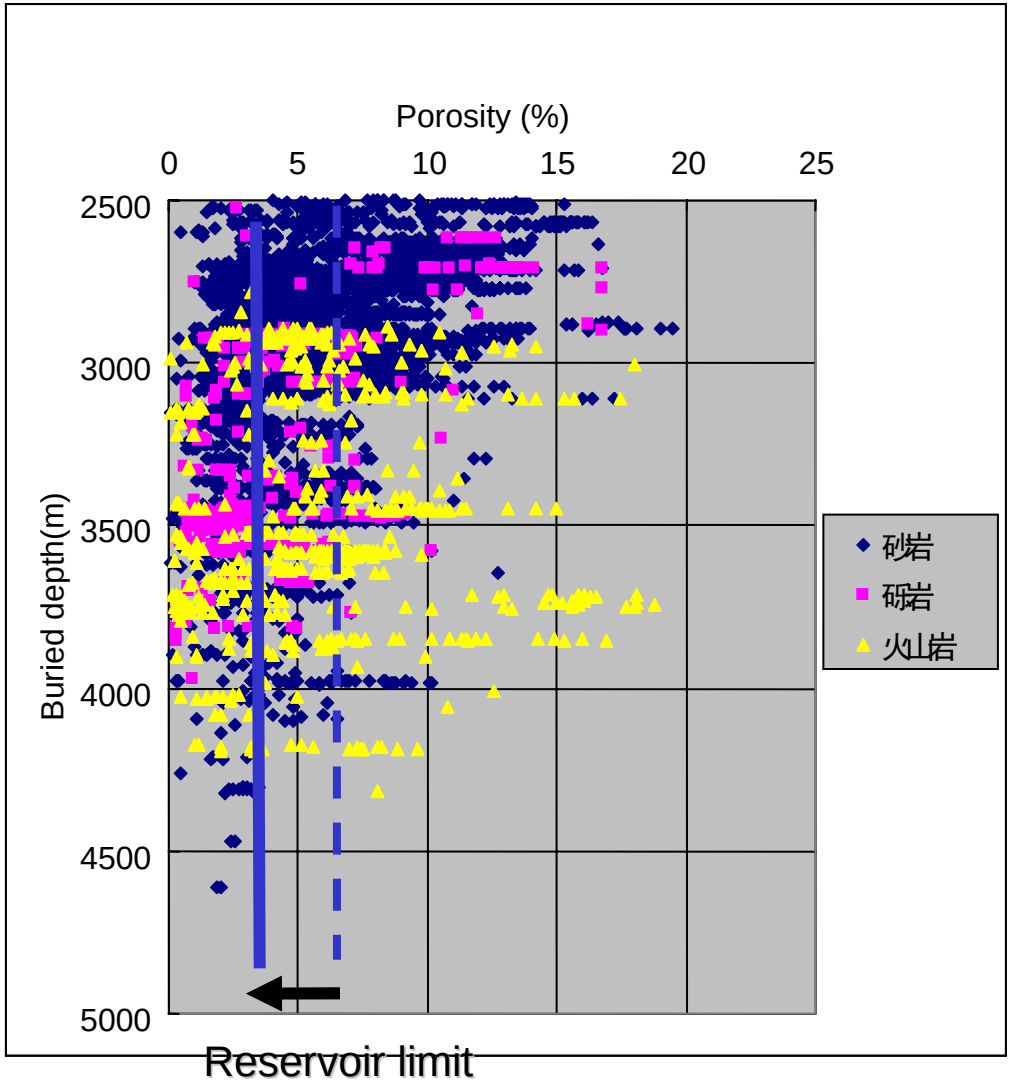


- **Due to variety of volcanic rock, conventional saturation calculating method is not adaptable to saturation calculation**
- **Explore and initially use NML to calculate it, the lithology influence has been overcome**
- **Interpreted coincidence ratio of gas and water is up to 91%**

Efficient and economic drilling

Air drilling accelerates drilling speed by 6-7 times

Advanced stimulation techniques lower reservoir requirements



For example：

Shengshen 202 well

3.9-5.5％ porosity

Daily gas production of

237,997m^3 after fracturing

Concluding remark

- Did we significantly underestimate the hydrocarbon resource potential in volcanic rocks?

- Will volcanic rock become one of the most important targets for deep exploration in many of the world's sedimentary basins?

- What lesson can we learn from the recent experience in China?

Thank you!