China University of Petroleum

油气储层研究中心
Petroleum reservoir research center

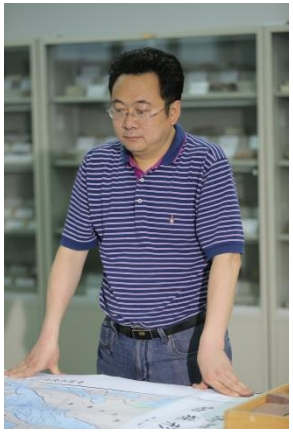
Petroleum Reservoir Research Center

Qingdao. China

- 1.Introduction
- 2.Research Field
- 3.Research highlights
- 4.Research Key Point

油气储层研究中心
Petroleum reservoir research center

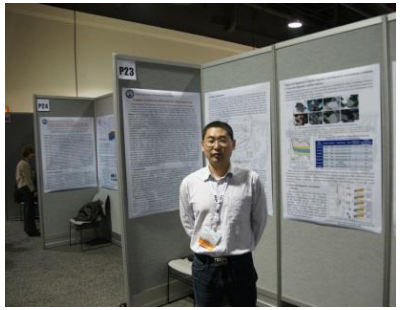
◆ Introduction



Prof. Cao Yingchang

Prof. Liu Keyu

Prof. Chen Zhonghong



Associate-prof. Wang Yanzhong

Associate-prof. Meng Fanchao

Dr. Wang Jian

Dr. Yuan Guanghui

Dr. Liang Chao

Dr. Xi Kelai

Dr. Liu Jianliang

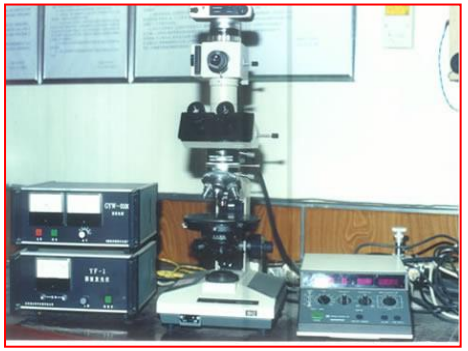
◆ Introduction

Provincial Key Laboratory

Polarizing microscope

Image analysis system

Linkam Ts-600 stage

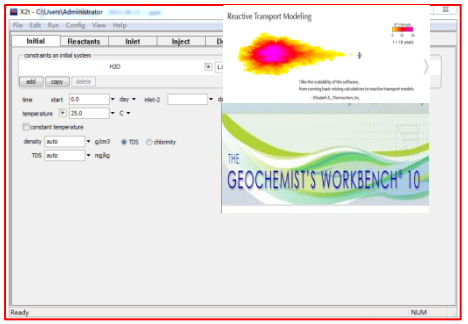


CL - microscope

Laser Scanning Confocal Microscope (LSCM)

SEM
COXEM EM-30

Water-rock interaction modelling system



Geochemist's Workbench

◆ Introduction

Center Spirits：

Openning & Cooperation

Innovation & Development

Durham University, University of Oslo, Curtin University, Aarhus University

6 doctor students and young teachers supported by CSC

Durham University，UK

University of Oslo, Norway

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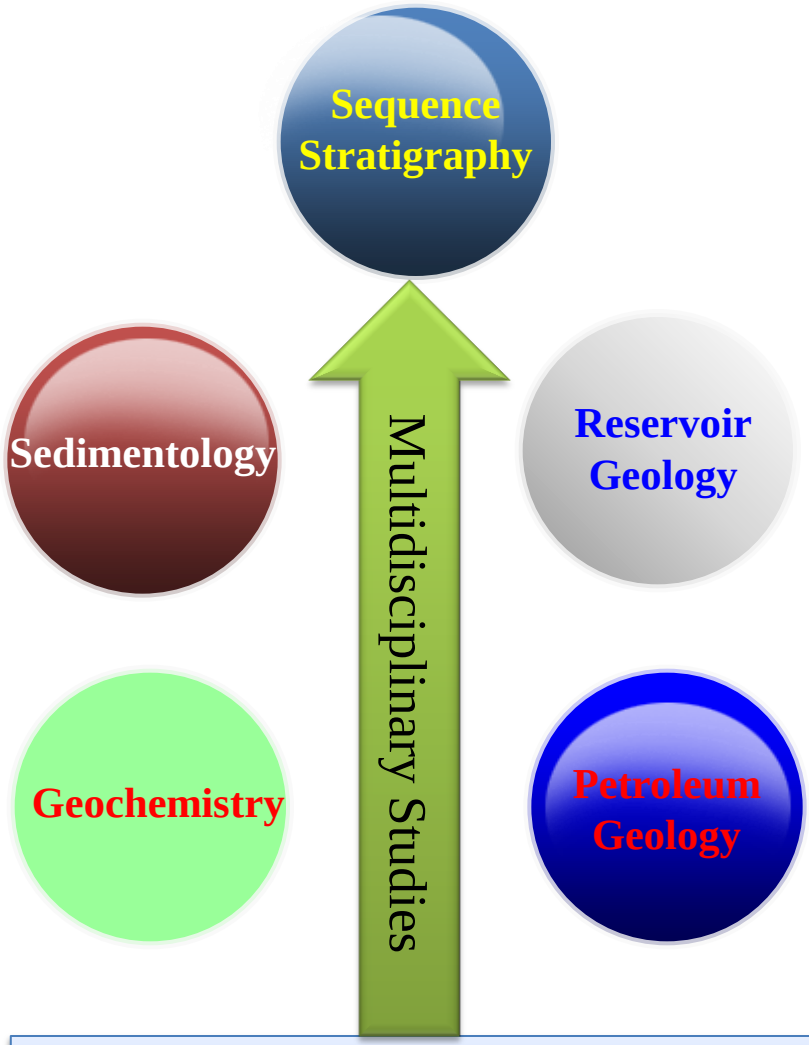
油气储层研究中心
Petroleum reservoir research center

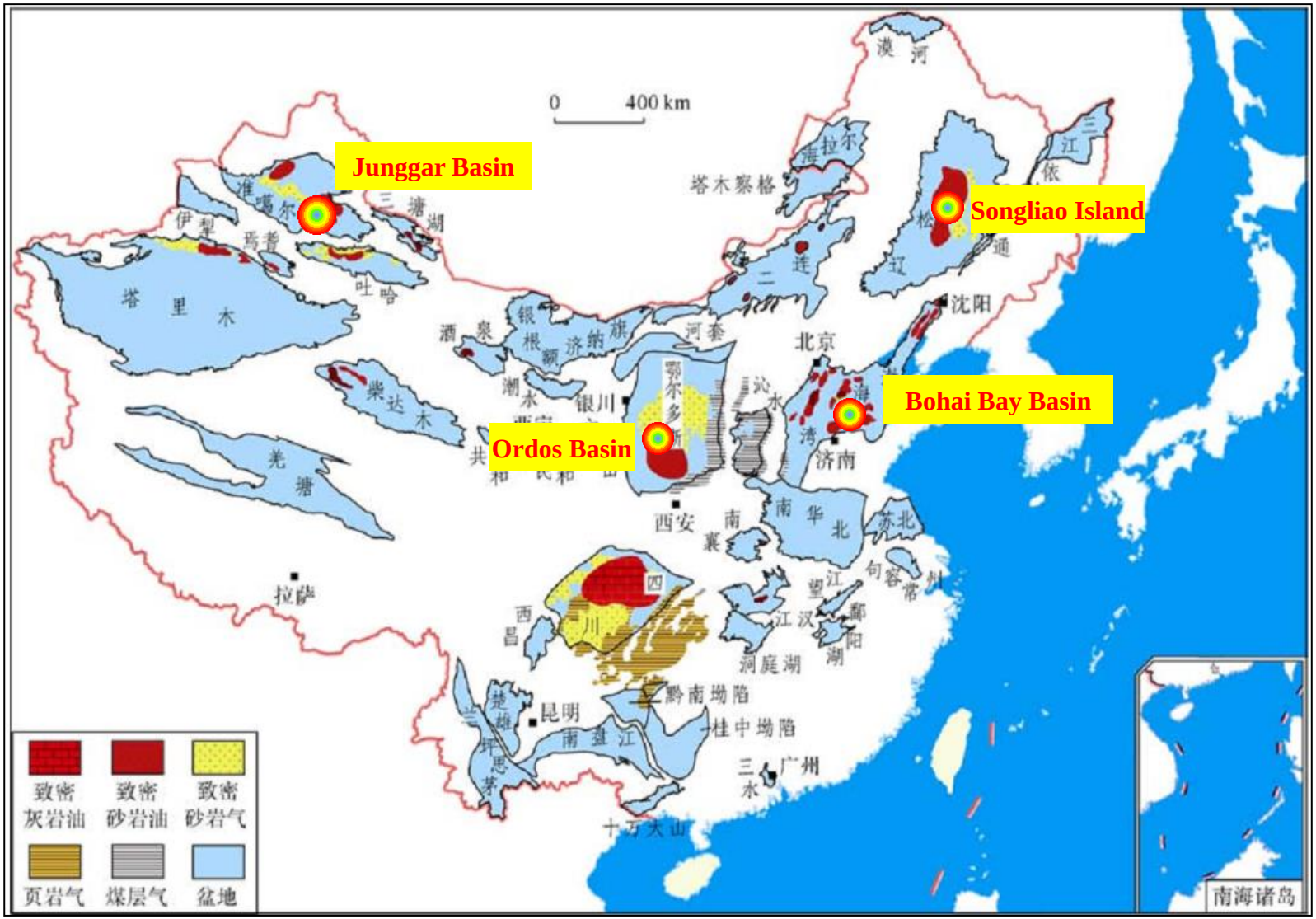
◆ Research Field



1. Sequence stratigraphy in lacustrine basin
2. Sedimentology in lacustrine basin
3. Petroleum reservoir geology
4. Unconventional Petroleum geology

Petroleum Reservoir Research Center → **Main Research Field**

◆ Research Field



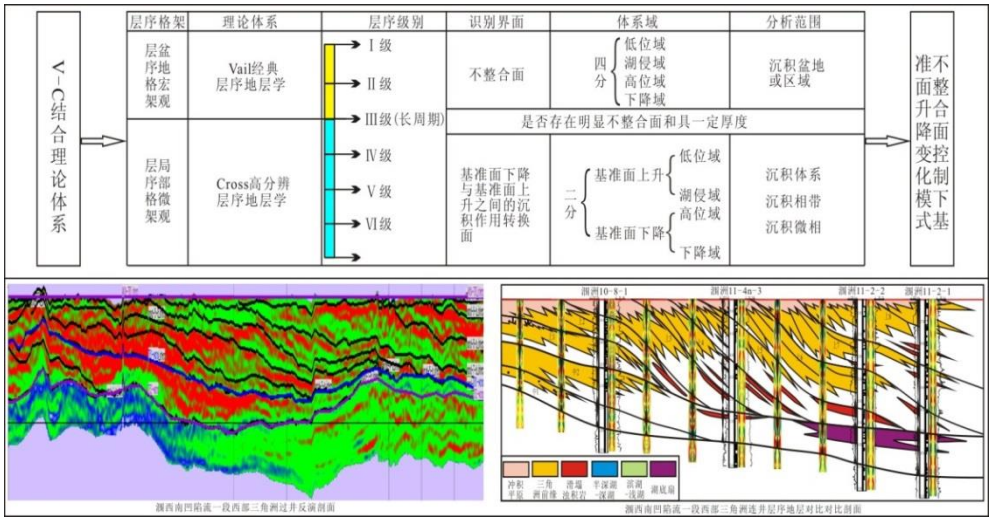
◆ Research Field

➢ Field -1

Sequence stratigraphy in lacustrine basins

Proposed the theory that the sequence stratigraphy patterns are controlled by basin architectures, the sand-bodies are constrained by sequence architecture, and the hydrocarbon distribution are restrained by sequence interfaces. Put forward an integrated research process based on Vail-Cross research system on study of sequence stratigraphy.

Research achievements published on the journal of ‘Petroleum Exploration and Development’, ‘Acta Geologica Sina’, and in the book of ‘Sequence stratigraphy in rift basin’.

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RESEARCH PAPER

Sequence structure and non-structural traps of the Paleogene in the Weixi'nan Sag, Beibuwan Basin

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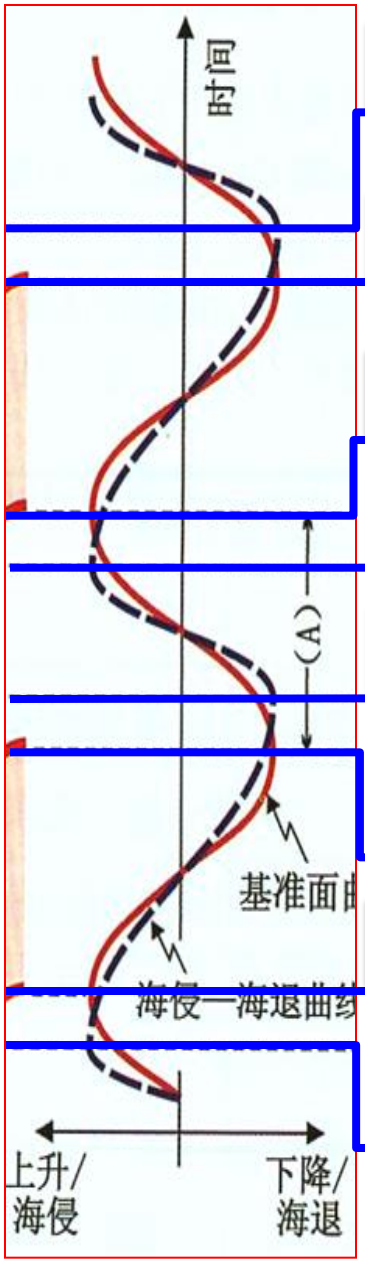
2. Zhanjiang Branch of CNOOC Ltd., Zhanjiang 524057, China

Abstract: Based on Vail sequence stratigraphic theory and analysis of seismic and logging information, the sequence in the Paleogene Liushagang and Weizhou formations in the Weixi'nan Sag is classified, the strata framework of sequence is defined and established, the characteristics of sequence structure are analyzed and the distribution of non-structural traps is revealed. One first-order sequence boundary, two second-order sequence boundaries, eight third-order sequence boundaries and ten third-order sequences are identified in the Liushagang and Weizhou Formations. According to the characteristics of sequence boundary structure, the third-order sequence boundaries can be divided into three types: type T1, type T2, and type T3. And according to the characteristics of sequence stratigraphic structure, the ten third-order sequences can be classified into four types: one-divided sequence, two-divided sequence, three-divided sequence, and four-divided sequence. The favorable areas for the development of stratigraphic overlap traps are above type T1 and type T3 sequence boundaries, while the unconformity barrier traps are developed below type T2 and type T3 sequence boundaries. The favorable development periods of lithologic traps are the early period of three-divided sequence and four-divided sequence and the late period of two-divided sequence and four-divided sequence.

Key words: sequence stratigraphy; sequence boundary; sequence structure; non-structural trap; Weixi'nan Sag


国家科学技术进步奖
证 书
为表彰国家科学技术进步奖获得者，特颁发此证书。
项目名称：陆相湖盆层序地层学研究及其在油气勘探开发中的应用
奖励等级：二等
获 奖 者：操应长
证书号：2005-J-210-2-08-R03

Sequence stratigraphy in lacustrine basins



Regression→Transgression

MRS

Falling→ Rising

MBS

LST

FSST

RST

Rising → Falling

MDS

HST

Transgression → Regression

MFS

Regression → Transgression

MRS

TST

Falling → Rising

MBS

LST

FSST

RST

Rising → Falling

MDS

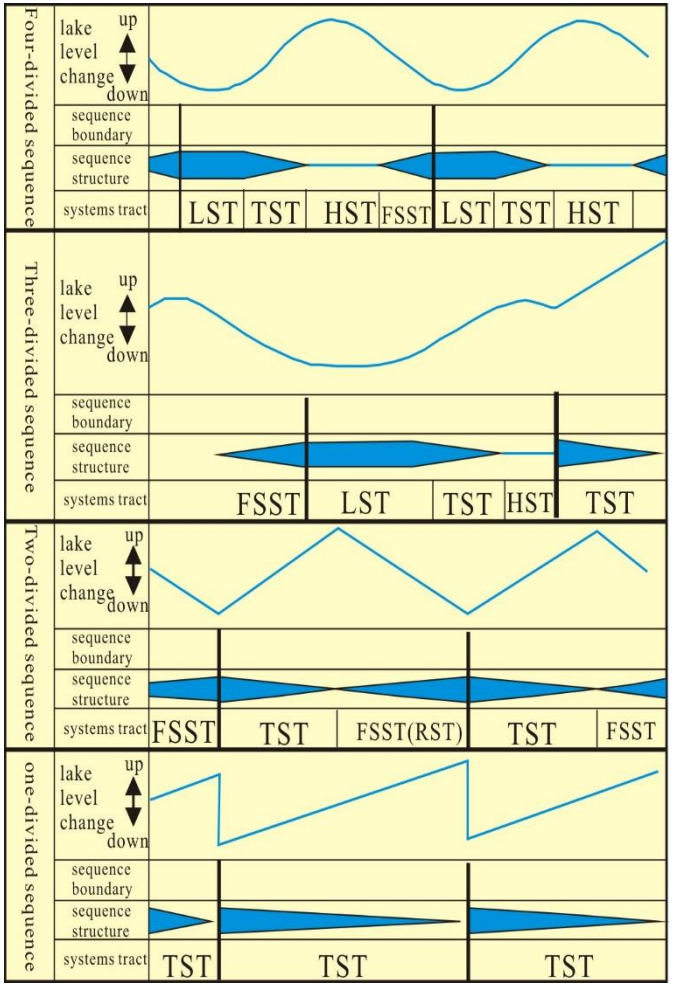
HST

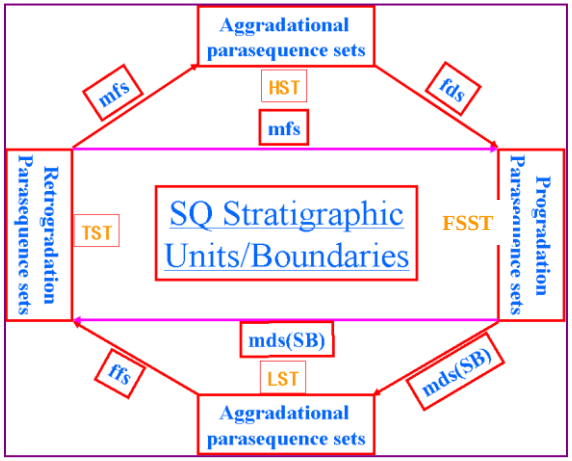
Transgression → Regression

MFS

Sequence stratigraphy in lacustrine basins

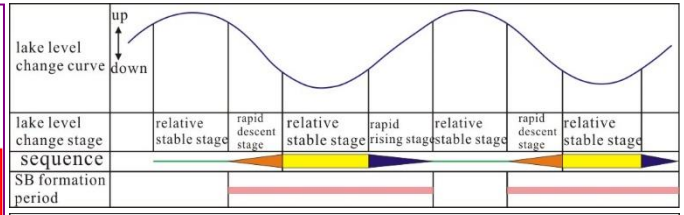
Sequence Stratigraphic Structure

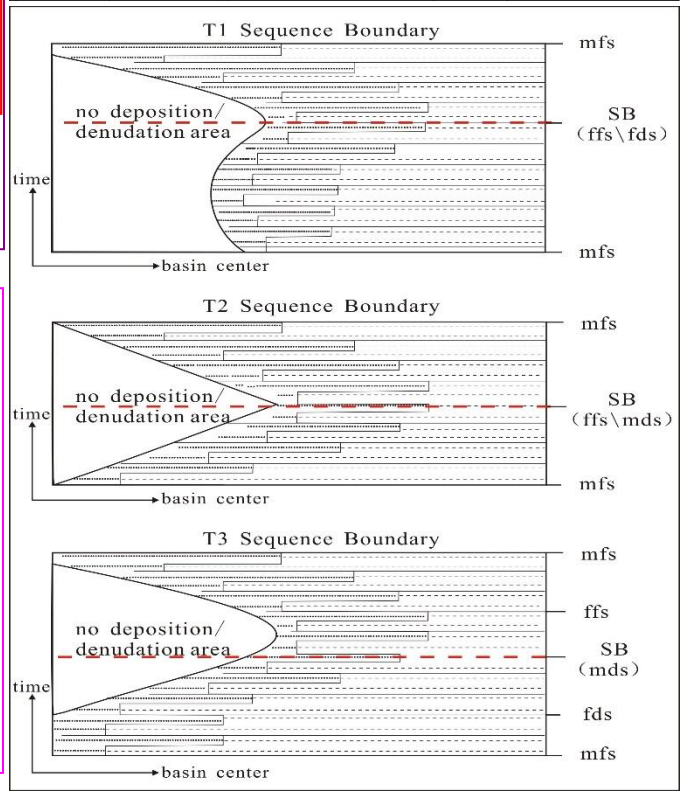




An ideal and complete relative lake level change curve is a sine curve. Because of tectonic activity, climate and sediment supply the change curve may miss some stages.

Sequence Boundary Structure





Sequence stratigraphy in lacustrine basins

Integrated Vail-Cross sequence stratigraphy theory

Vail theory

Cross theory

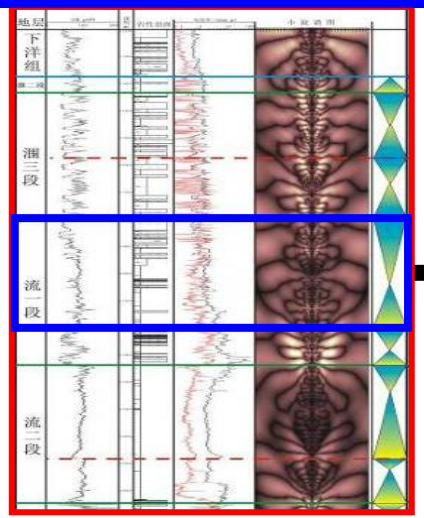
Unconformity and its equivalent conformity

Change of base level based on unconformity

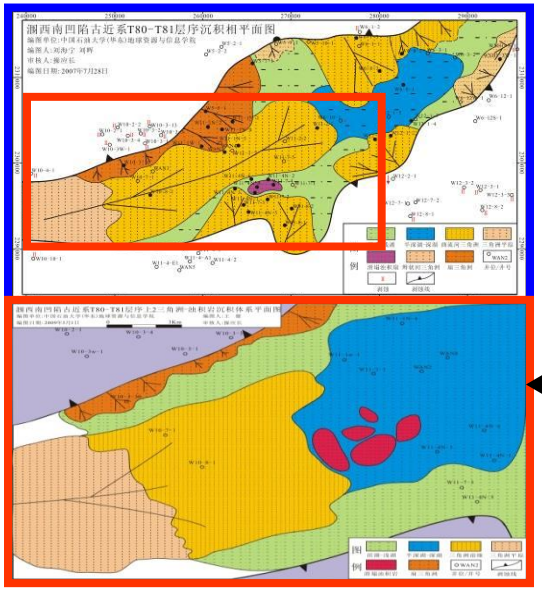
sedimentary transform surfaces and cycle of base level cycle

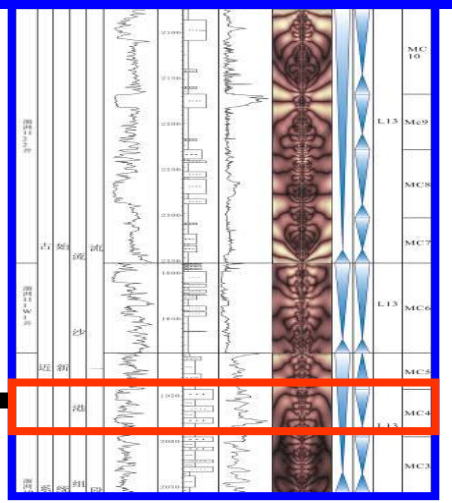
Regional sequence stratigraphic framework

high resolution sequence stratigraphic framework



1st – 3rd order sequence





4th – 6th order sequence

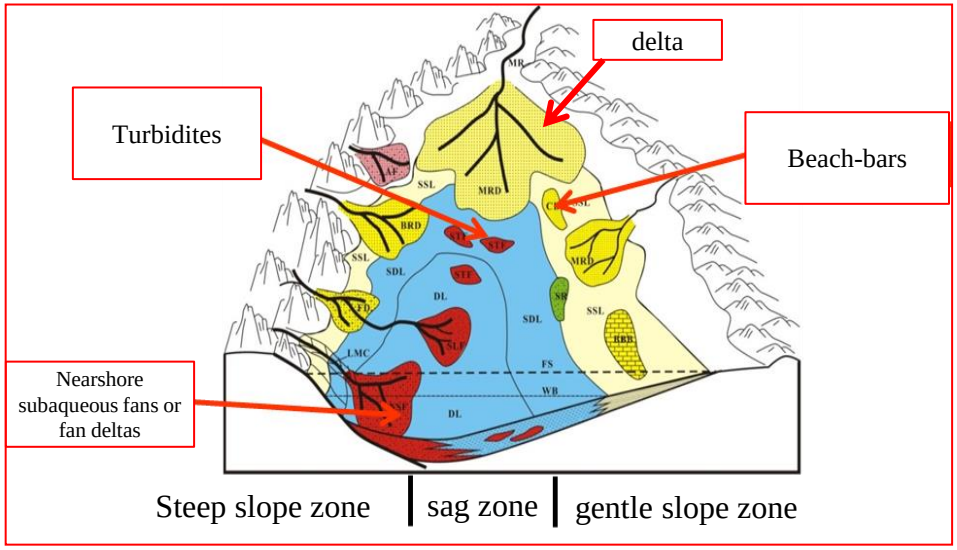
◆ Research Field

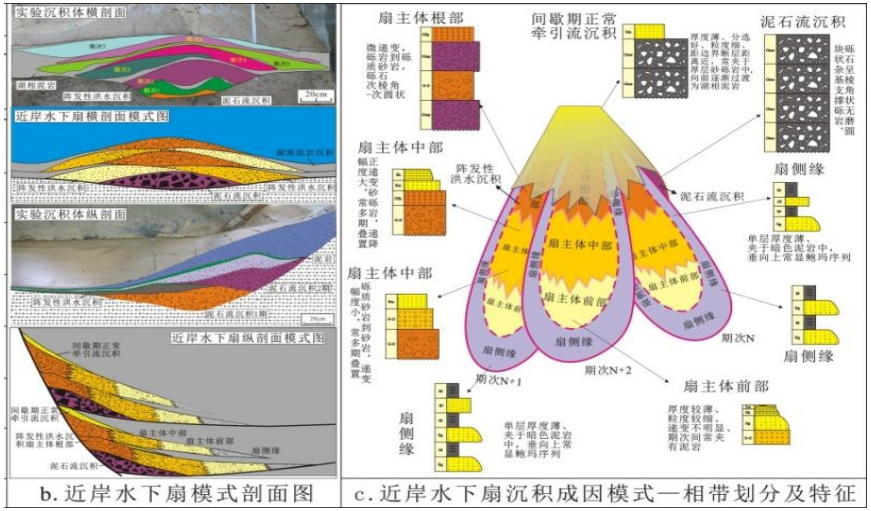
➢ Field -2

Sedimentology in lacustrine basins

We proposed sedimentary models for different types of complicated sandbodies including nearshore subaqueous fans, turbidites and beach-bar, characterization techniques of these complicated sandbodies, and prediction methods on distribution of such sandbodies.

Research achievements published on the journal of ‘Energy Exploration and Exploitation and Acta Sedimentologica Sinica, and in the book ‘sequence stratigraphy and sedimentology of sandbodies’.

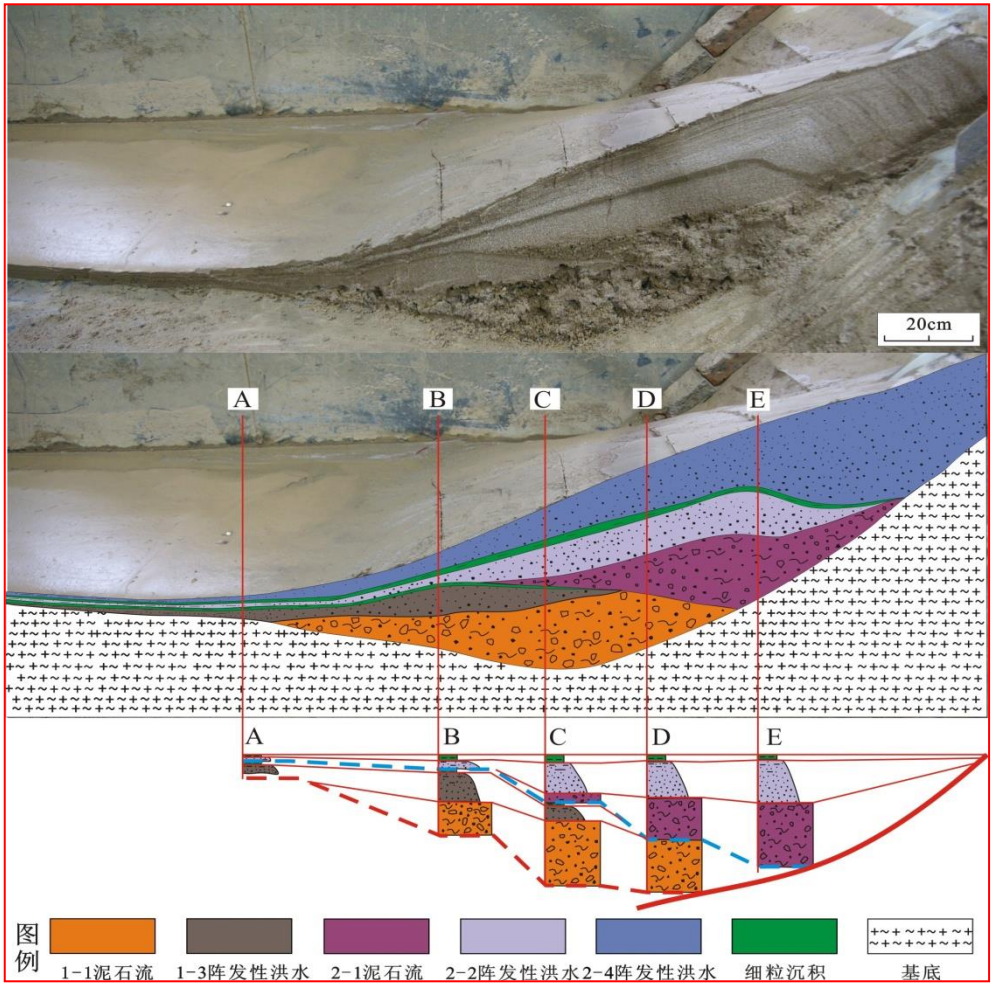


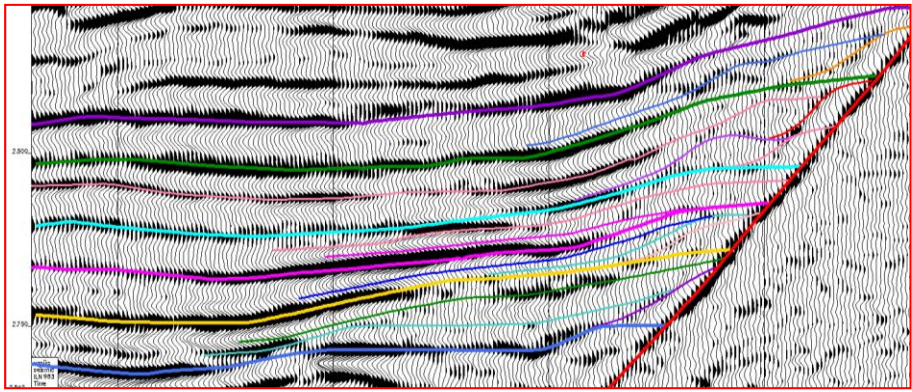


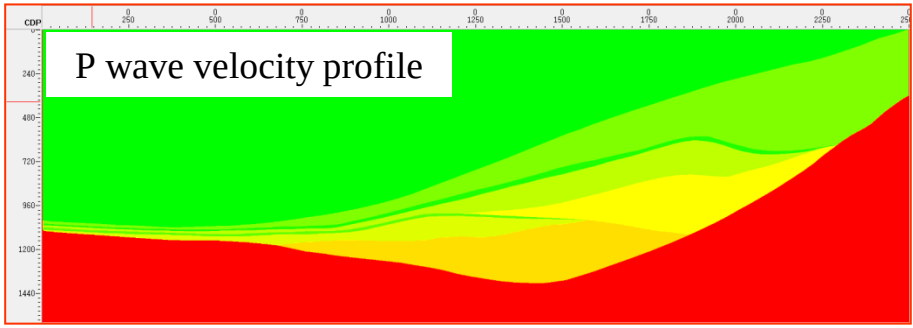
b. 近岸水下扇模式剖面图　　c. 近岸水下扇沉积成因模式—相带划分及特征

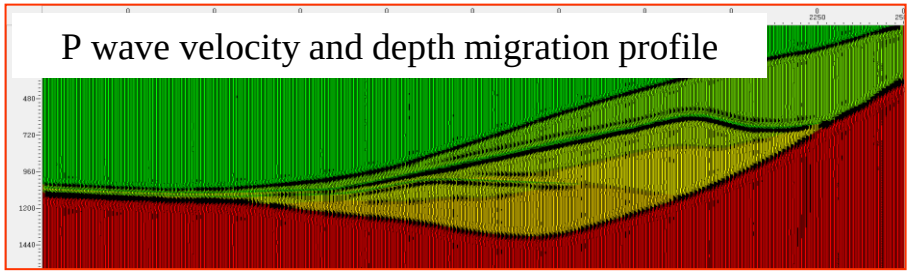
Sedimentology in lacustrine basins

Nearshore subaqueous fans in steep slope zone of rift basins







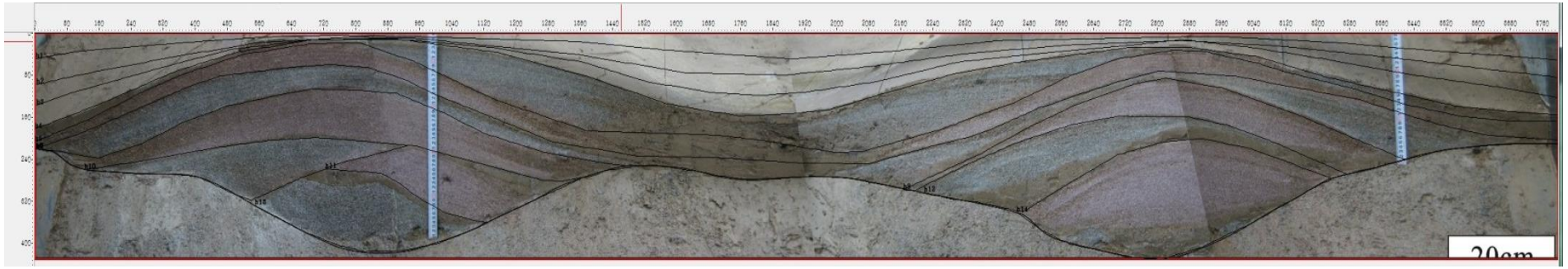


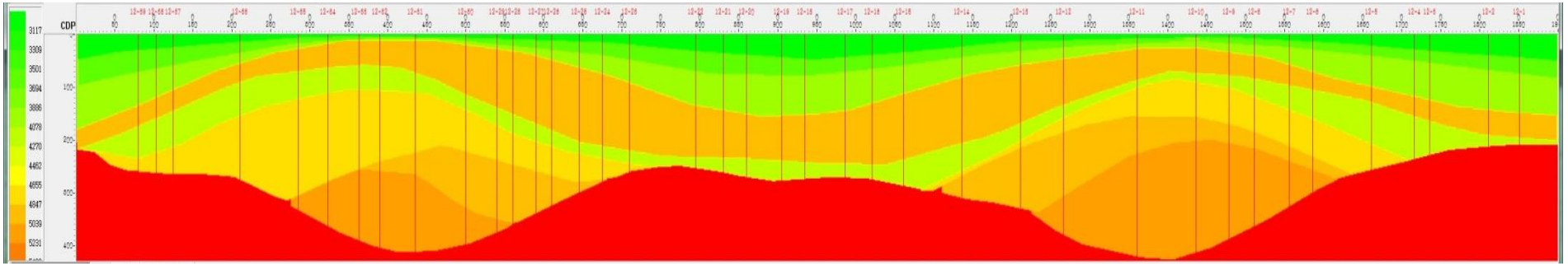
Stable mudstone identified during different depositional unit

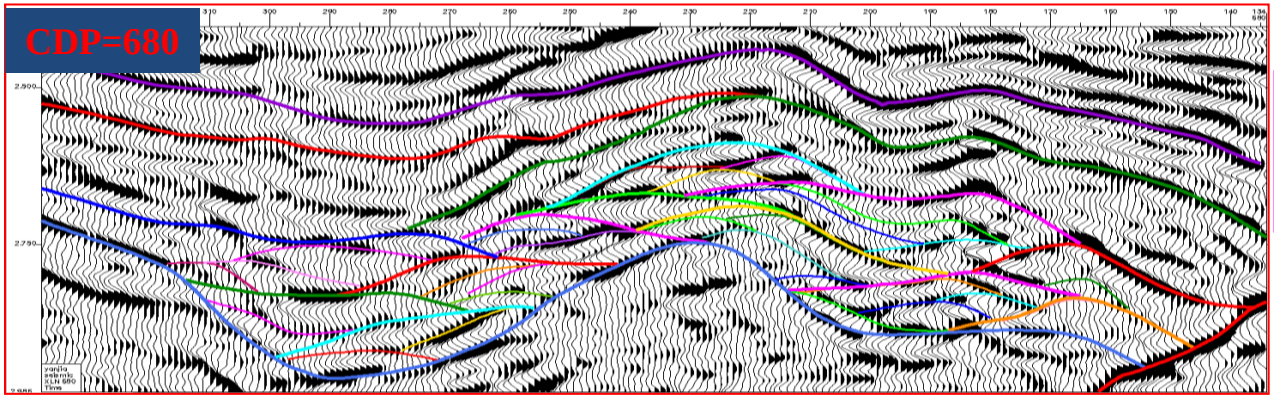
scouring surface+lithofacies transition surface

Sedimentology in lacustrine basins

Nearshore subaqueous fans in steep slope zone of rift basins



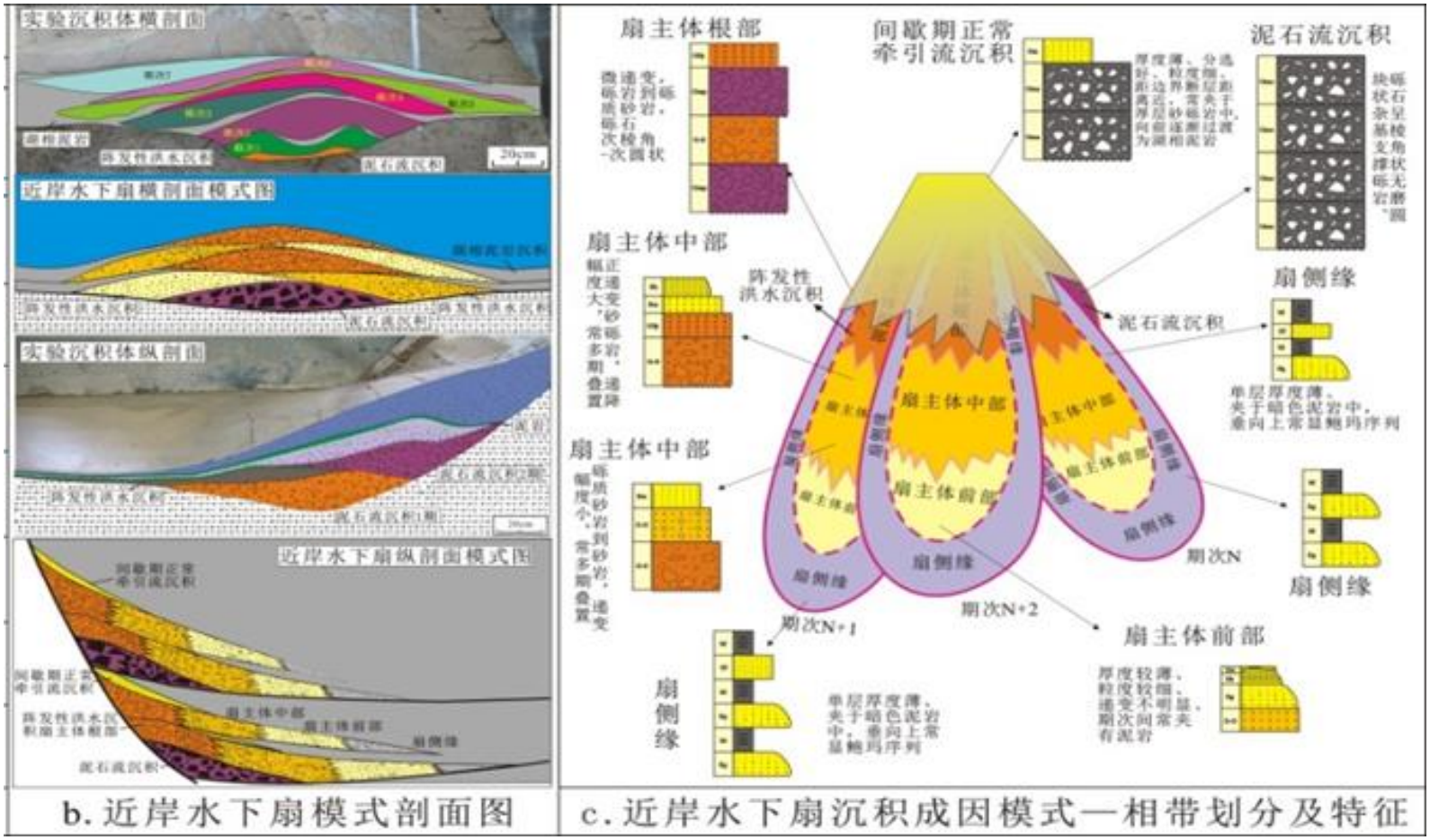




Compensated deposition
Migrate laterally

Sedimentology in lacustrine basins

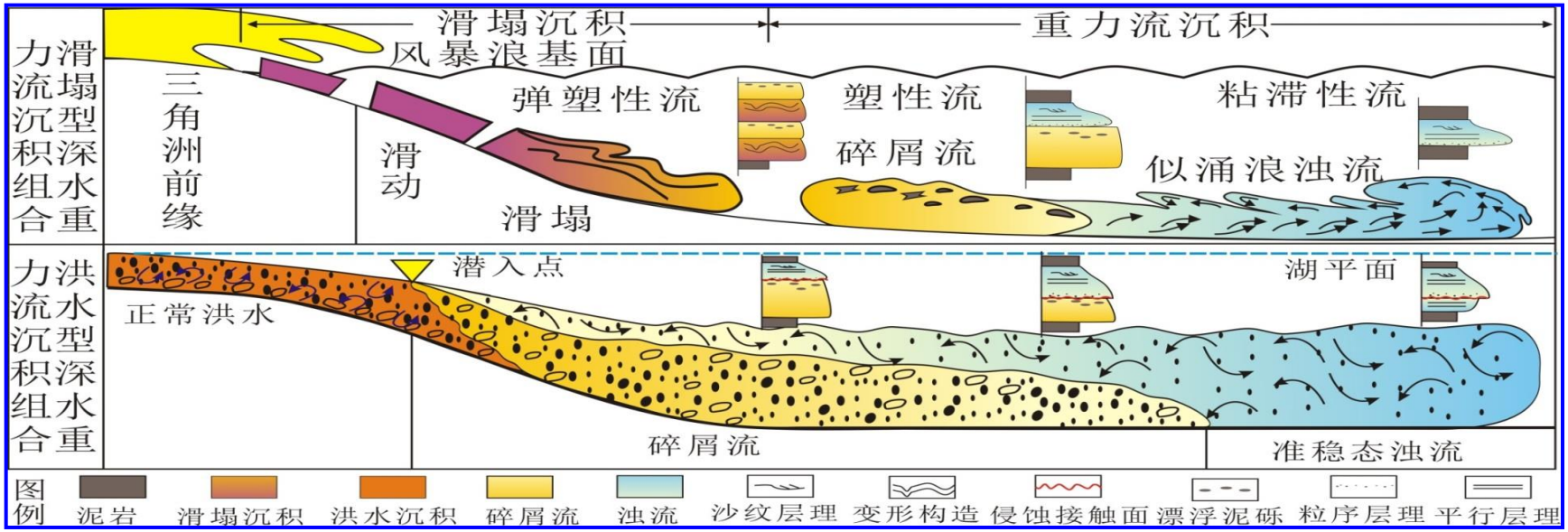
Nearshore subaqueous fans in steep slope zone of rift basins

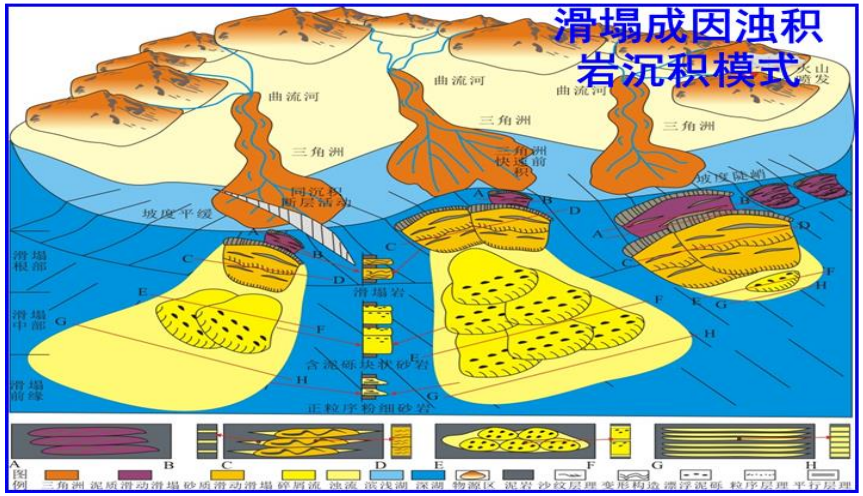


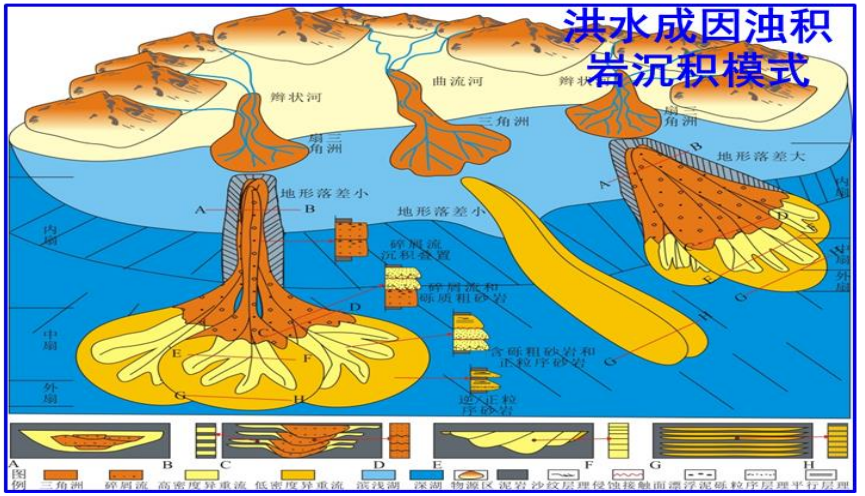
Genetic model of nearshore subaqueous fans

Sedimentology in lacustrine basins

Gravity flow deposits in subsag zone

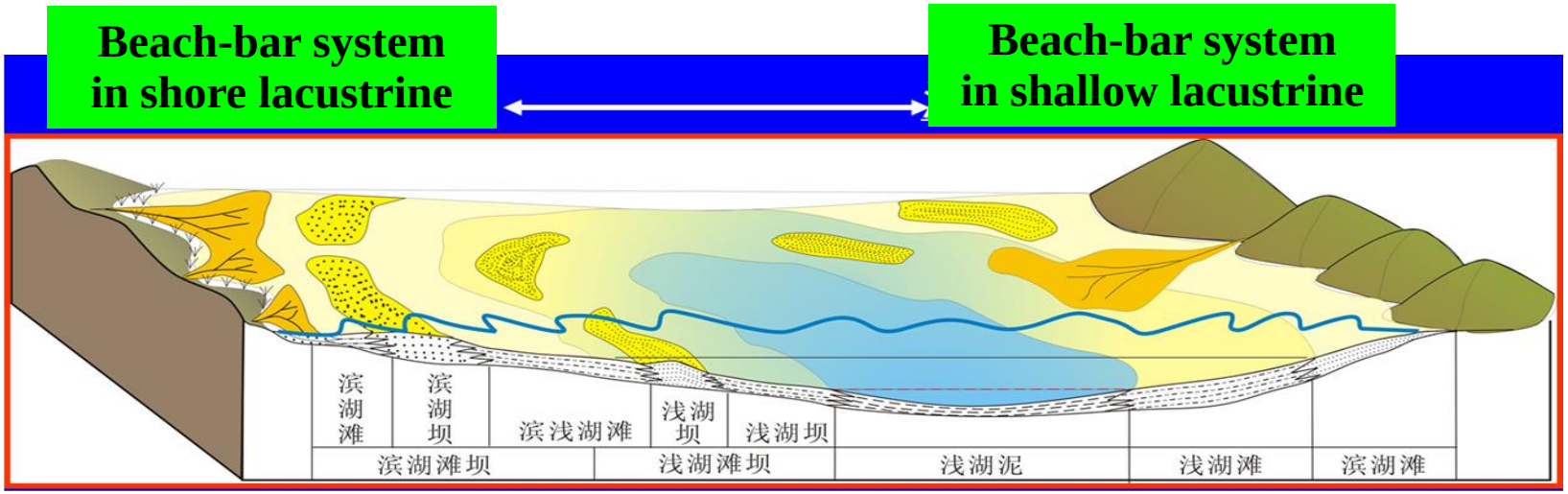


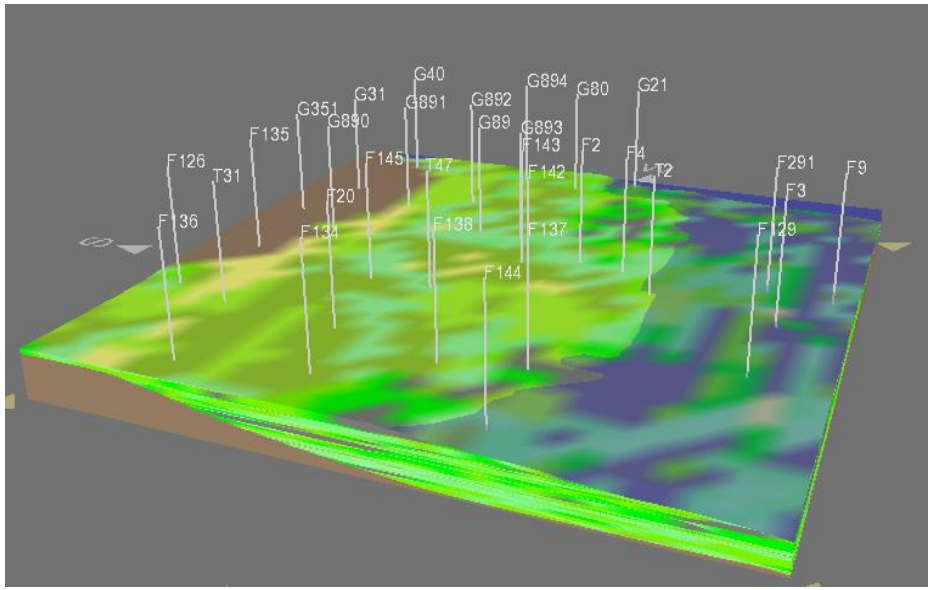


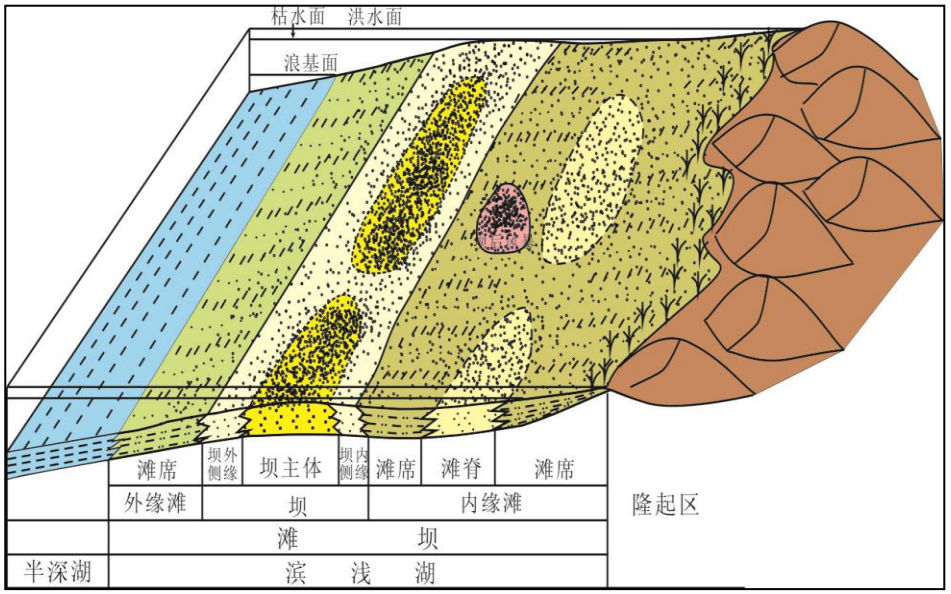


Sedimentology in lacustrine basins

Beach-bars in gentle slope zone of rift basins







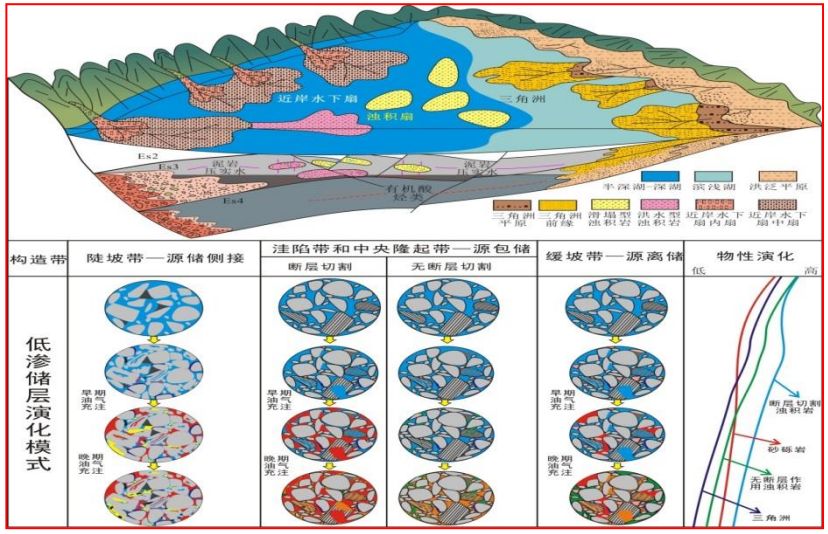
◆ Research Field

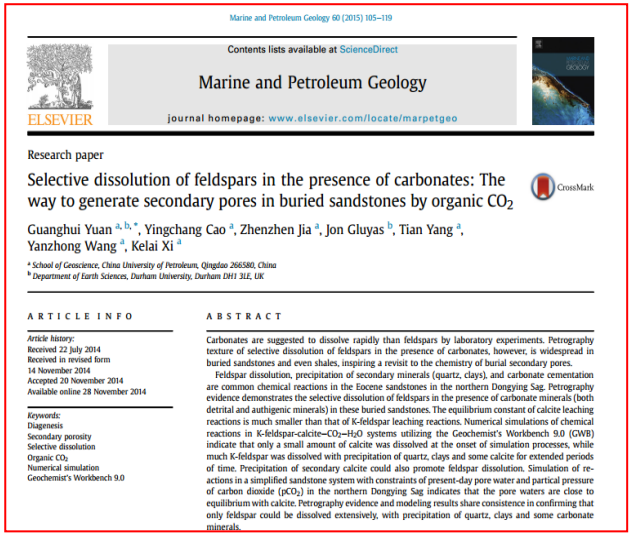
➢ Field -3

Petroleum reservoir Geology

Based on study of quantitative diagenesis on sandstone reservoirs, the characterization and recovery of physical properties, the genesis of low-permeability reservoir and deeply buried high quality reservoir were proposed. And a reservoir quality evaluation method using multi parameters was proposed.

Results published on the journal of ‘AAPG Bulletin, Marine and Petroleum Geology, Sedimentology, et al, .





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Contents lists available at ScienceDirect

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journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Selective dissolution of feldspars in the presence of carbonates: The way to generate secondary pores in buried sandstones by organic CO_2

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Keywords:
Diagenesis
Secondary porosity
Selective dissolution
Organic CO_2
Numerical simulation
Geochemist's Workbench 9.0

ABSTRACT

Carbonates are suggested to dissolve rapidly than feldspars by laboratory experiments. Petrography texture of selective dissolution of feldspars in the presence of carbonates, however, is widespread in buried sandstones and even shales, inspiring a revisit to the chemistry of burial secondary pores.

Feldspar dissolution, precipitation of secondary minerals (quartz, clays), and carbonate cementation are common chemical reactions in the Eocene sandstones in the northern Dongying Sag. Petrography evidence demonstrates the selective dissolution of feldspars in the presence of carbonate minerals (both detrital and authigenic minerals) in these buried sandstones. The equilibrium constant of calcite leaching reactions is much smaller than that of K-feldspar leaching reactions. Numerical simulations of chemical reactions in K-feldspar-calcite–CO_2–H_2O systems utilizing the Geochemist's Workbench 9.0 (GWB) indicate that only a small amount of calcite was dissolved at the onset of simulation processes, while much K-feldspar was dissolved with precipitation of quartz, clays and some calcite for extended periods of time. Precipitation of secondary calcite could also promote feldspar dissolution. Simulation of reactions in a simplified sandstone system with constraints of present-day pore water and partical pressure of carbon dioxide (pCO_2) in the northern Dongying Sag indicates that the pore waters are close to equilibrium with calcite. Petrography evidence and modeling results share consistence in confirming that only feldspar could be dissolved extensively, with precipitation of quartz, clays and some carbonate minerals.

山东省科学技术奖

证 书

为表彰山东省科学技术奖获得者，特颁发此证书。

项目名称：断陷湖盆复杂砂体精细表征与储层评价关键技术及其应用

获奖等级：壹等

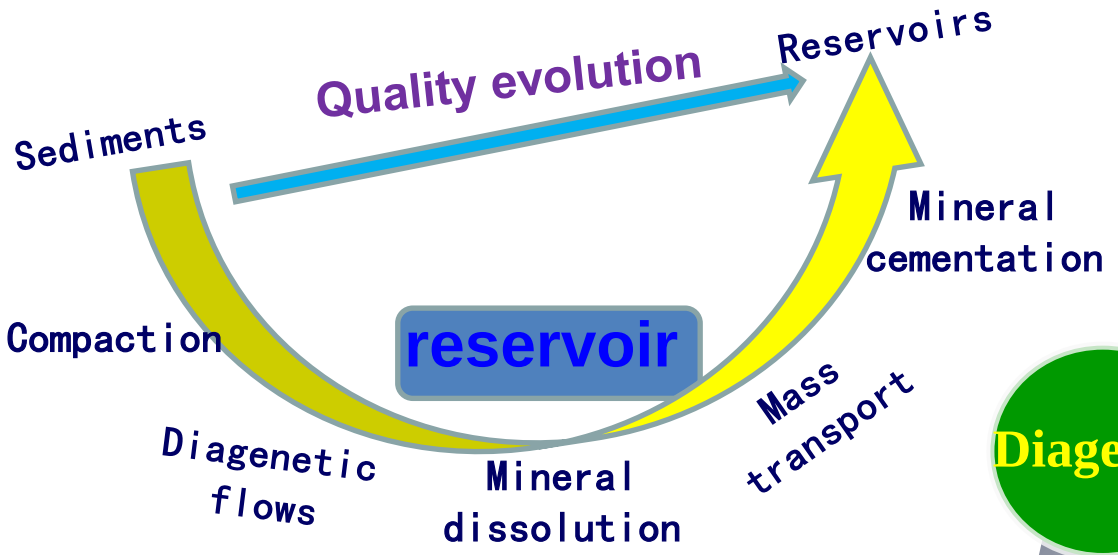
获 奖 者：操应长（第壹位）

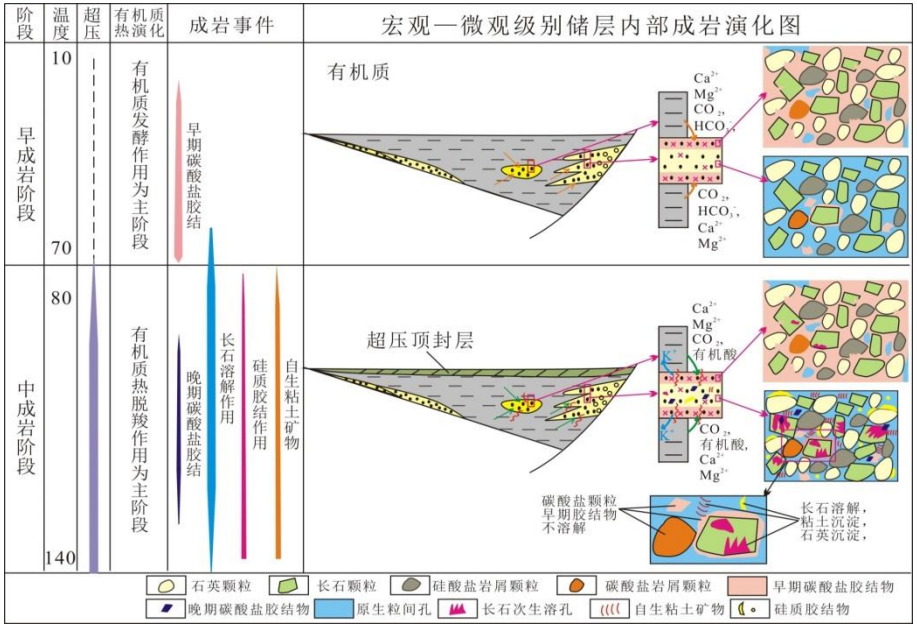
类　　别：科技进步奖

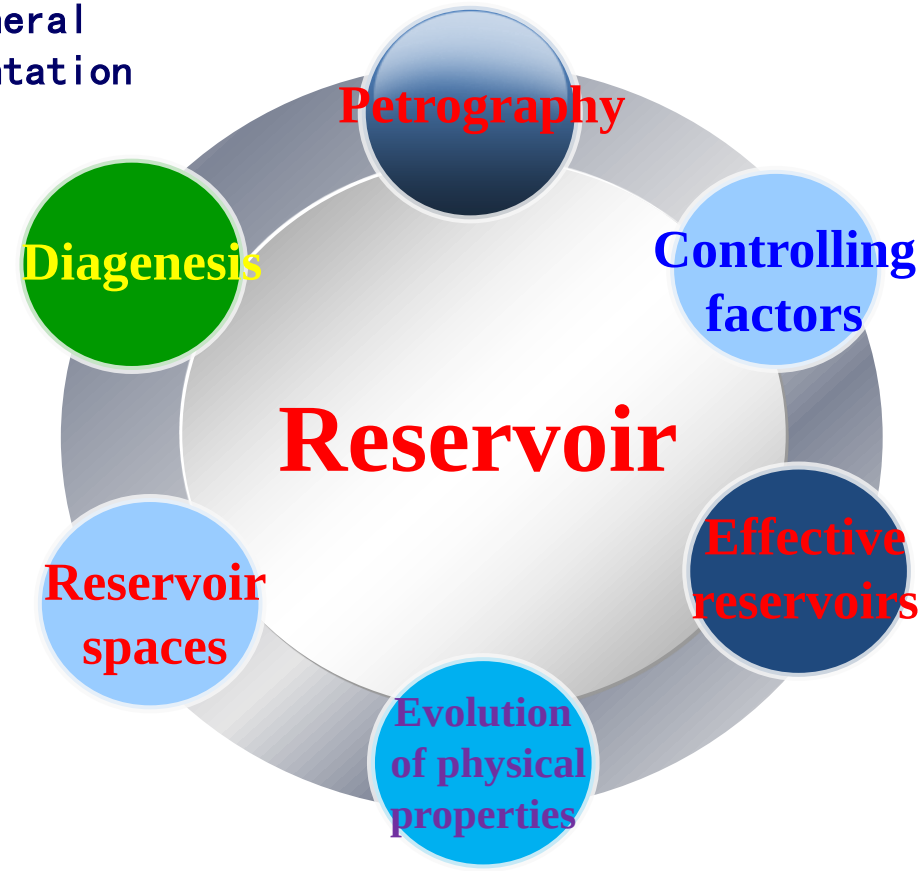
证书号：JB2012-1-15-R01

2012年11月22日

Petroleum reservoir Geology







油气储层研究中心
Petroleum reservoir research center

Petroleum reservoir Geology

Quantitative reservoir geology

Quantitative characterization of macro parameters

Decipher of genesis on micro-scale

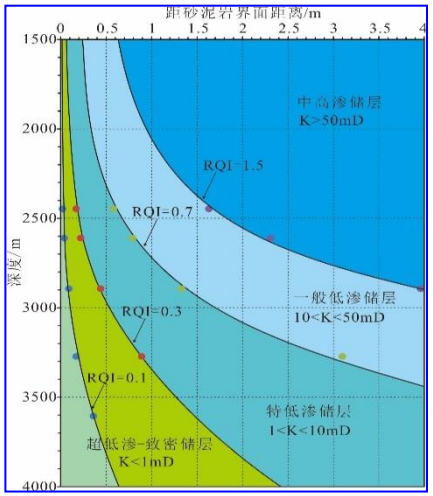
Characterization and evolution of poroperm and controlling factors

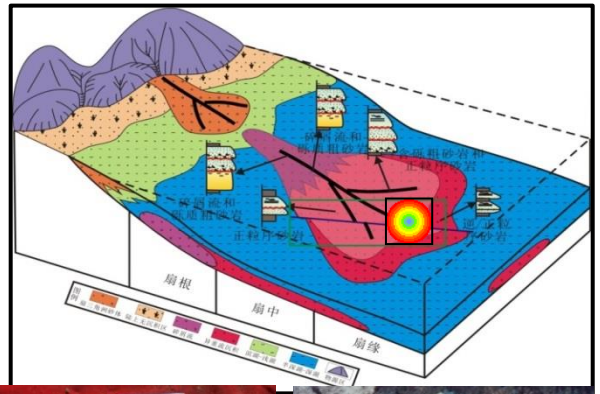
Reservoir quality evolution and origin of high quality reservoir with constraints of various factors

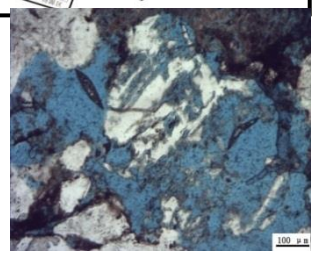
Quantitative diagenesis and pore evolution

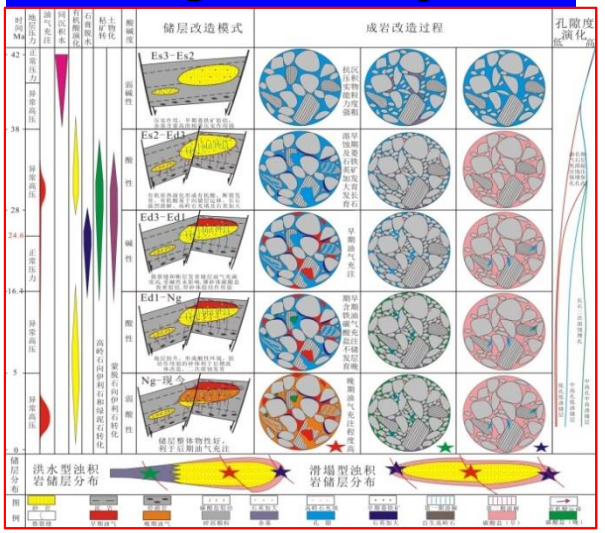
Quantitative characterization of physical properties

Evolution model of diagenesis and pores









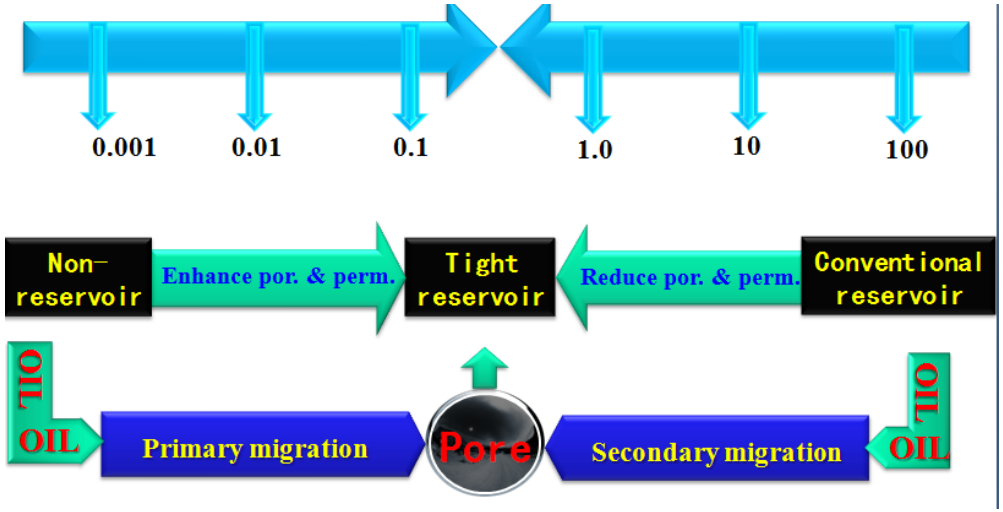
◆ Research Field

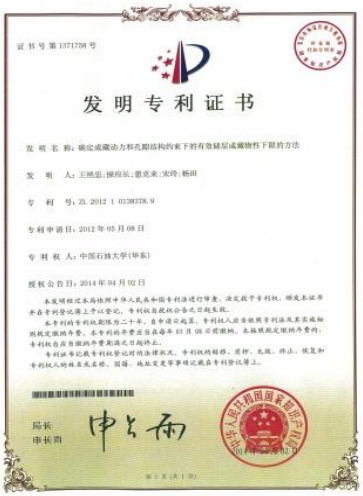
➢ Field -4

Unconventional Petroleum Geology

Put forward the classification scheme for tight fine grained rocks, formed the macro property and micro pore throat structure characterization technique for tight reservoirs, and revealed the genetic mechanism of tight oil and gas reservoirs.

Results published on the journal of ‘Sedimentary Geology’, ‘Marine and Petroleum Geology’, ‘Petroleum Exploration and Development’, ‘Acta Petrolei Sinica’, and 1 patent granted.





Unconventional Petroleum geology

Tight fine grained oil and gas reservoir geology

classification scheme for tight fine grained rocks

Diagenetic evolution and oil accumulation

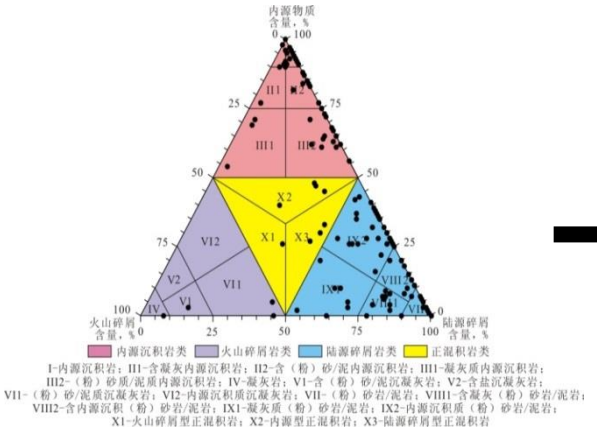
Composition and its content of tight fine grained rocks

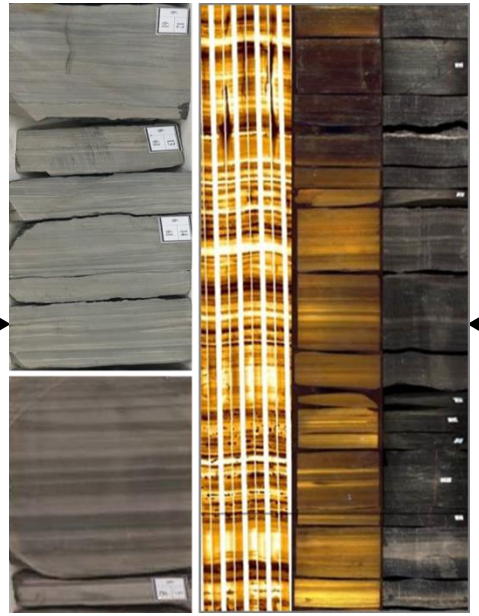
Genetic mechanism of tight fine grained oil and gas reservoirs and “sweet spots” prediction

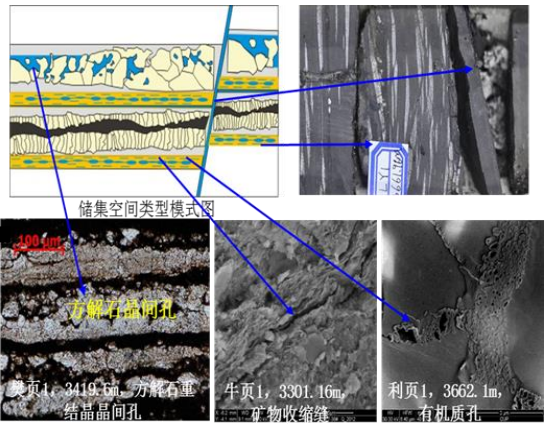
Pore formation and reservoir wettability of tight fine grained rocks

Four component and three end-members

Pore evolution and oiliness characteristics







Unconventional Petroleum geology

Tight sandstone oil and gas reservoir geology

Densification mechanism of tight sandstones

Digenetic evolution and poroperm evolution

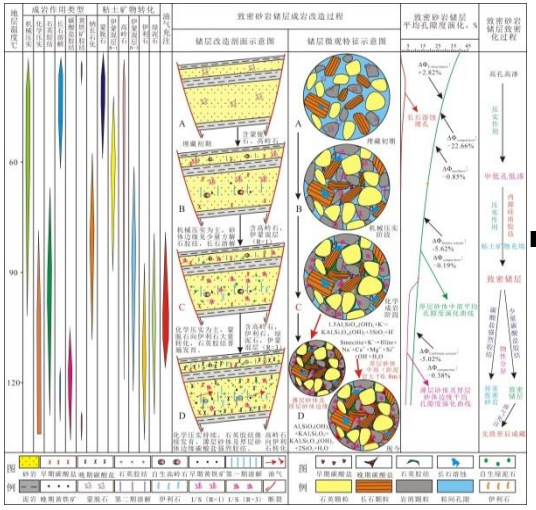
Diagenesis and physical property responses

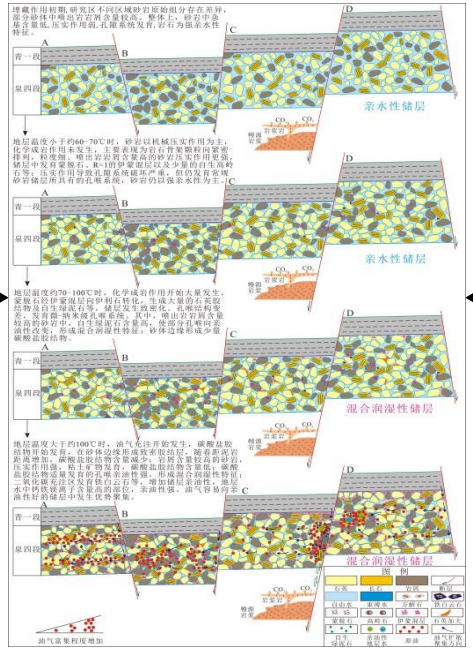
Genetic mechanism of tight sandstone oil and gas reservoirs and “sweet spots” prediction

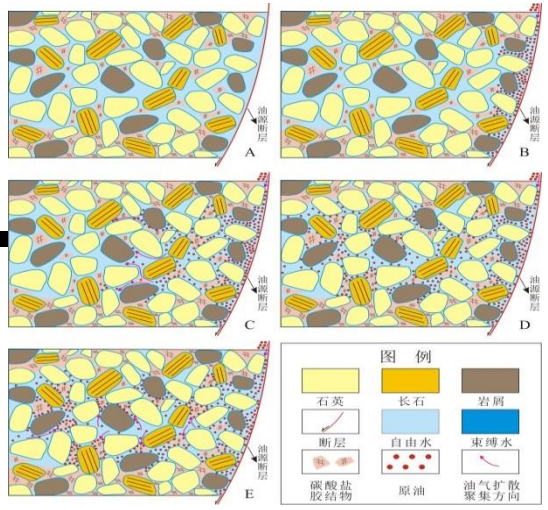
Oil charging and accumulation mechanism

Pore-throat structure and reservoir wettability

Reservoir properties and oiliness characteristics



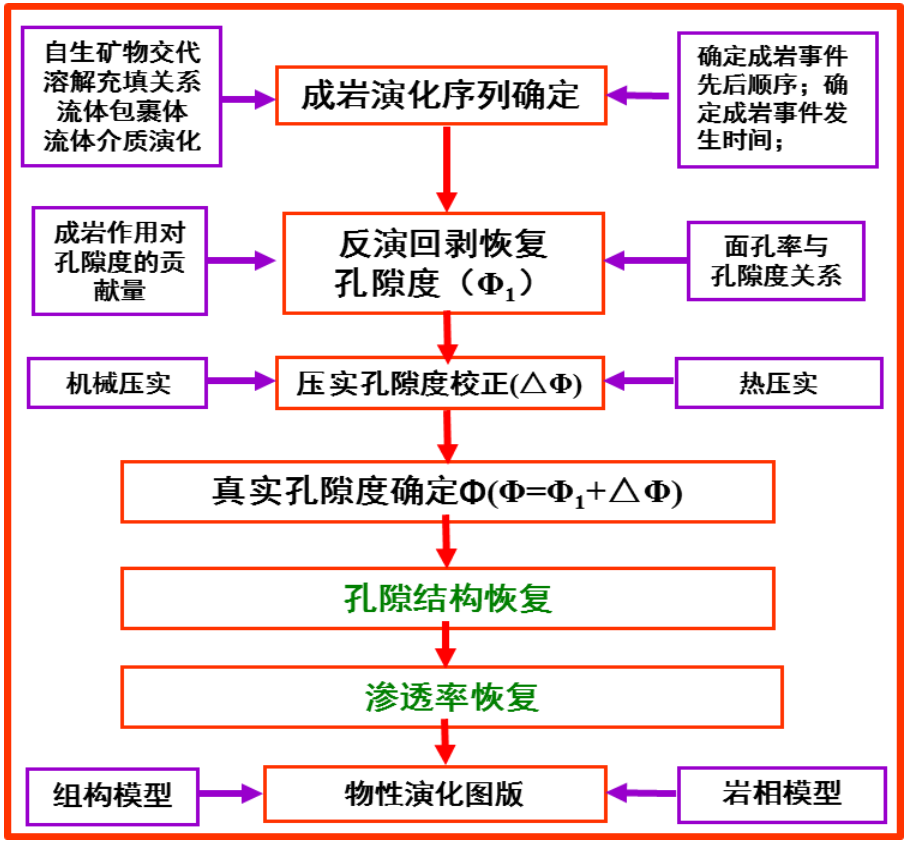


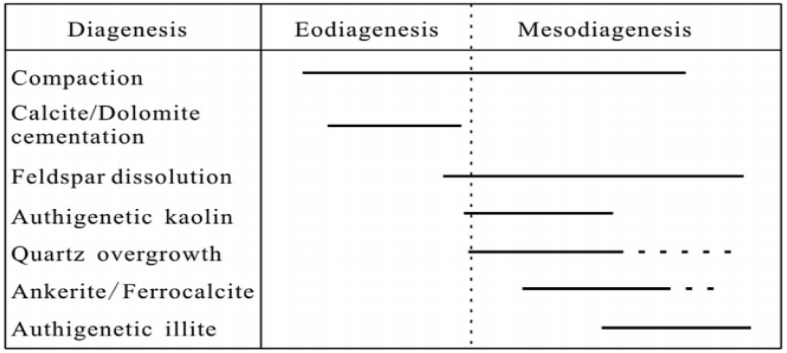


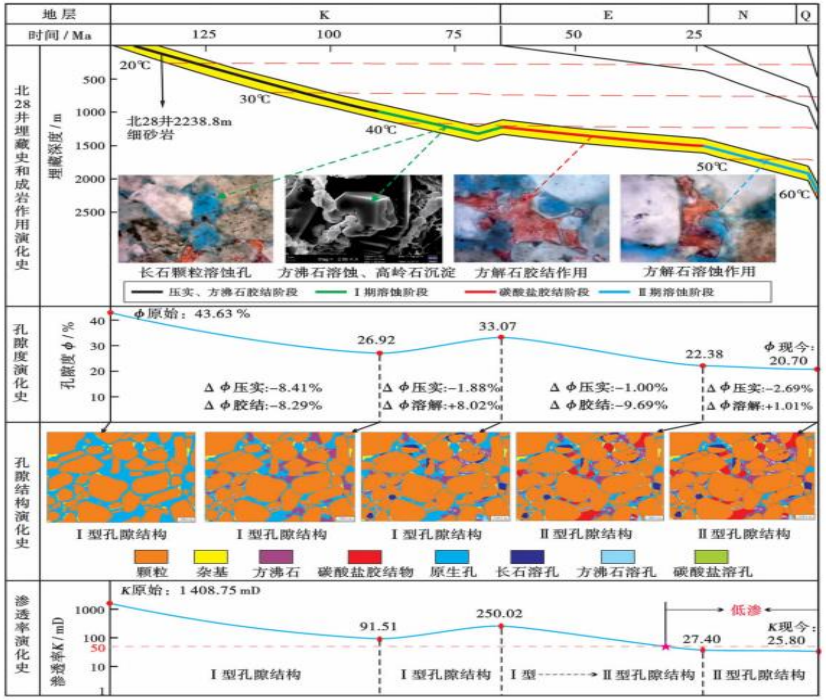
- 1.Introduction
- 2.Research Field
- 3.Research Highlights
- 4.Research Key Point

Highlight 1

Quantitative recovery technique of porosity and permeability with geological time based on diagenetic evolution sequence







Highlight 2

Secondary porosity generation hypothesis of selective dissolution of feldspars in presence of carbonate minerals.

① Open geochemical system: leaching of both feldspar and calcite

② Closed geochemical system: leaching of feldspar instead of calcite

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Research paper

Selective dissolution of feldspars in the presence of carbonates: The way to generate secondary pores in buried sandstones by organic CO_2

Guanghui Yuan [a, b, *], Yingchang Cao [a], Zhenzhen Jia [a], Jon Gluyas [b], Tian Yang [a], Yanzhong Wang [a], Kelai Xi [a]

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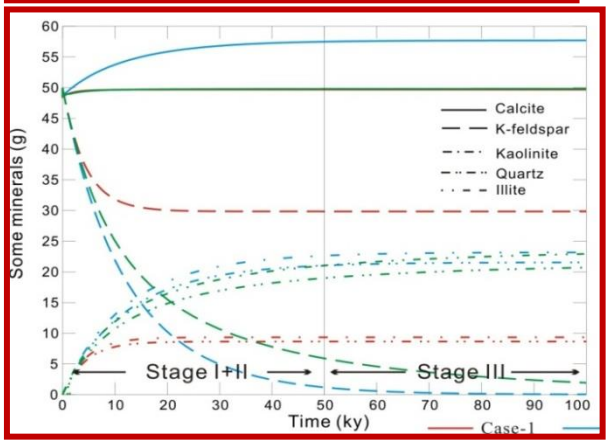
Geochemist's Workbench 9.0

ABSTRACT

Carbonates are suggested to dissolve rapidly than feldspars by laboratory experiments. Petrography texture of selective dissolution of feldspars in the presence of carbonates, however, is widespread in buried sandstones and even shales, inspiring a revisit to the chemistry of burial secondary pores.

Feldspar dissolution, precipitation of secondary minerals (quartz, clays), and carbonate cementation are common chemical reactions in the Eocene sandstones in the northern Dongying Sag. Petrography evidence demonstrates the selective dissolution of feldspars in the presence of carbonate minerals (both detrital and authigenic minerals) in these buried sandstones. The equilibrium constant of calcite leaching reactions is much smaller than that of K-feldspar leaching reactions. Numerical simulations of chemical reactions in K-feldspar-calcite–CO_2–H_2O systems utilizing the Geochemist's Workbench 9.0 (GWB) indicate that only a small amount of calcite was dissolved at the onset of simulation processes, while much K-feldspar was dissolved with precipitation of quartz, clays and some calcite for extended periods of time. Precipitation of secondary calcite could also promote feldspar dissolution. Simulation of reactions in a simplified sandstone system with constraints of present-day pore water and partical pressure of carbon dioxide (pCO_2) in the northern Dongying Sag indicates that the pore waters are close to equilibrium with calcite. Petrography evidence and modeling results share consistence in confirming that only feldspar could be dissolved extensively, with precipitation of quartz, clays and some carbonate minerals.



Highlight 3

Redistributional models of secondary pores and secondary minerals following the leaching of feldspars in sandstones.

① Open system: Leached feldspar = secondary pores

② Closed system: **Leached feldspar** = secondary pores+ secondary minerals

Feldspar dissolution, authigenic clays, and quartz cements in open and closed sandstone geochemical systems during diagenesis: Typical examples from two sags in Bohai Bay Basin, East China

Guanghui Yuan, Yingchang Cao, Jon Gluyas, Xiaoyan Li, Kelai Xi, Yanzhong Wang, Zhenzhen Jia, Peipei Sun, and Norman H. Oxtoby

ABSTRACT

Feldspar dissolution and precipitation of clays and quartz cements are important diagenetic reactions affecting reservoir quality evolution in sandstones with detrital feldspars. We examined two sets of sandstone reservoirs to determine whether the sandstone diagenetic systems were open or closed to the mass transfer of products from feldspar dissolution and its impact on reservoir quality. One of the reservoirs is the Eocene fan delta sandstone buried 2.5–4.0 km (1.5–2.5 mi) below sea level (BSL) in the Gaoliu (GL) area of the Nanpu sag, and the other is the Eocene

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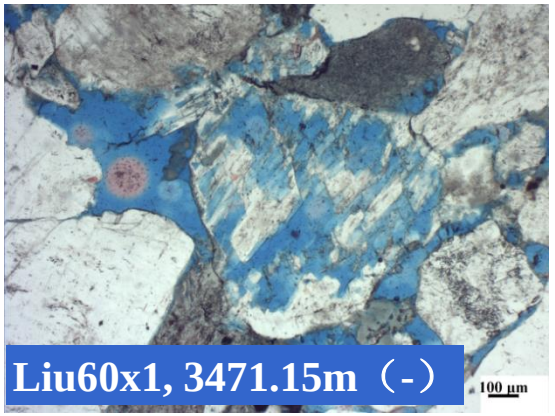
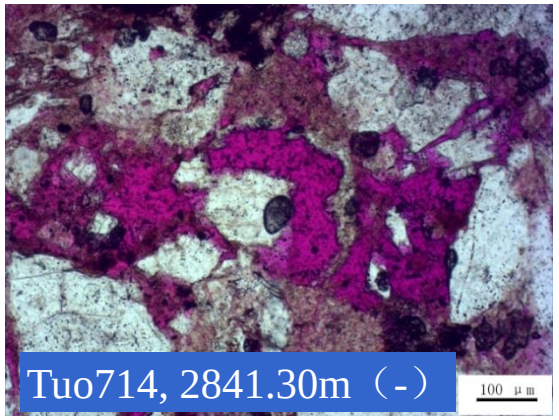
XIAOYAN LI ~ *Geology Department, School*



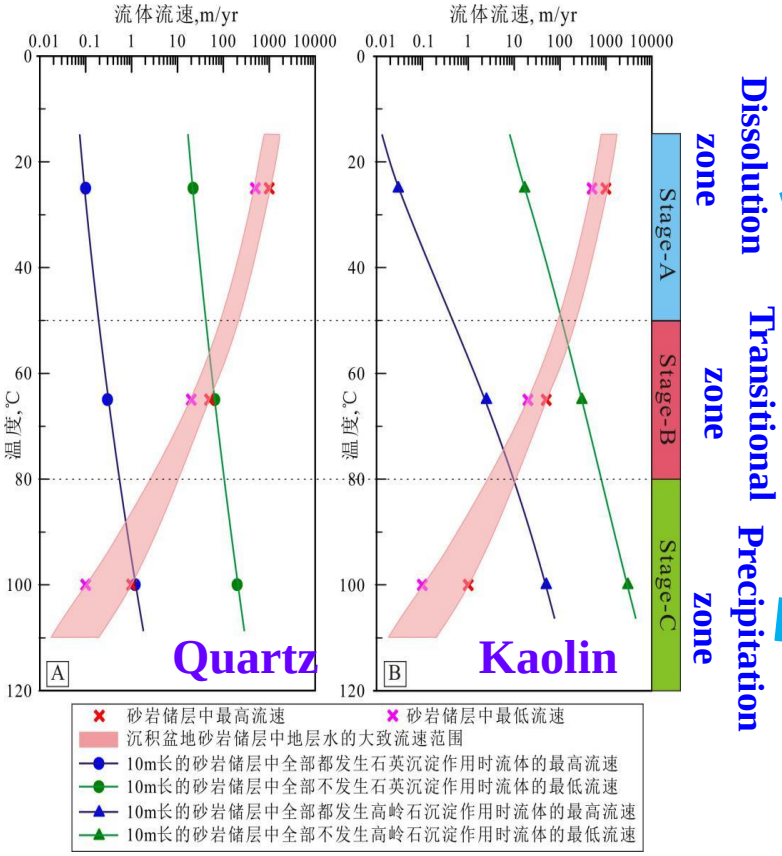


Highlight 3

Redistributional models of secondary pores and secondar minerals following the leaching of feldspars in sandstones.

① Open system: Leached feldspar = secondary pores

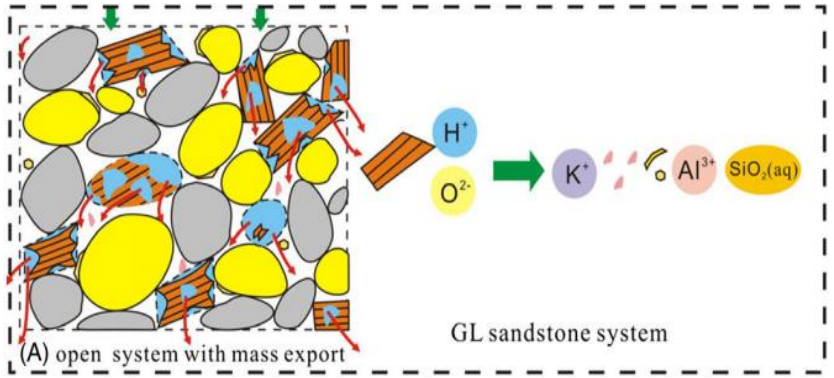
② Closed system: Leached feldspar = secondary pores+ secondary minerals



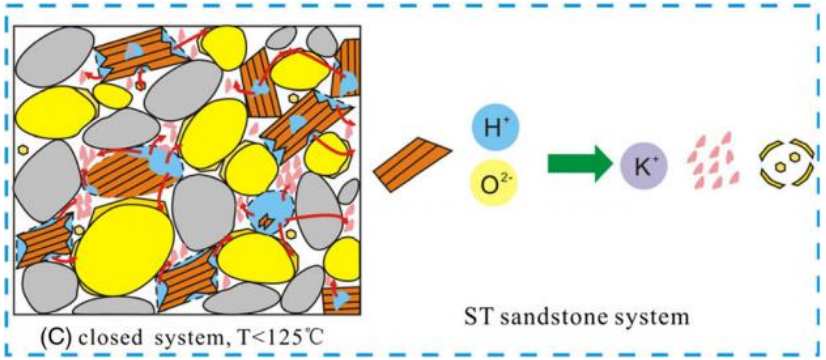
Dissolution zone

Transitional zone

Precipitation zone



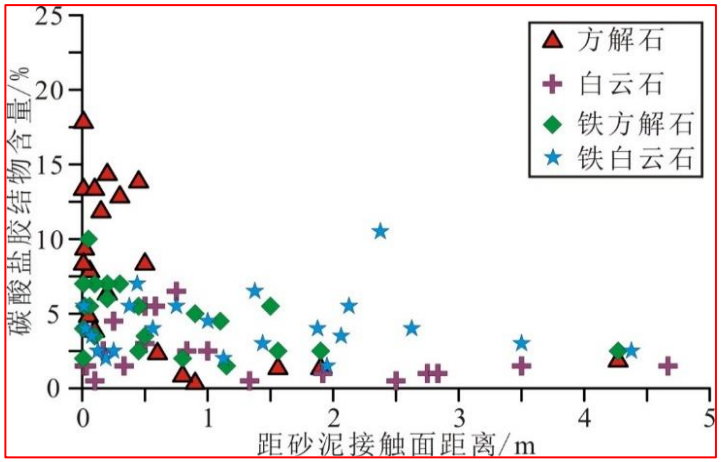
Open geochemical system

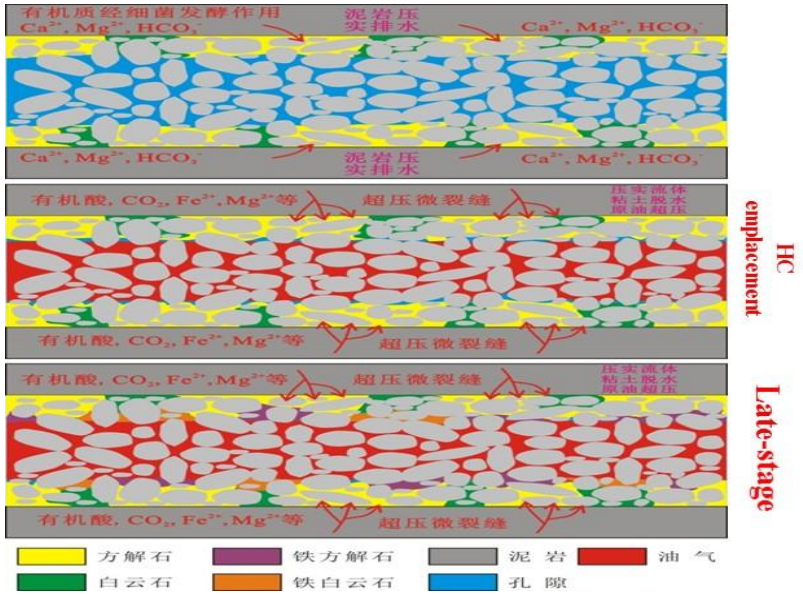


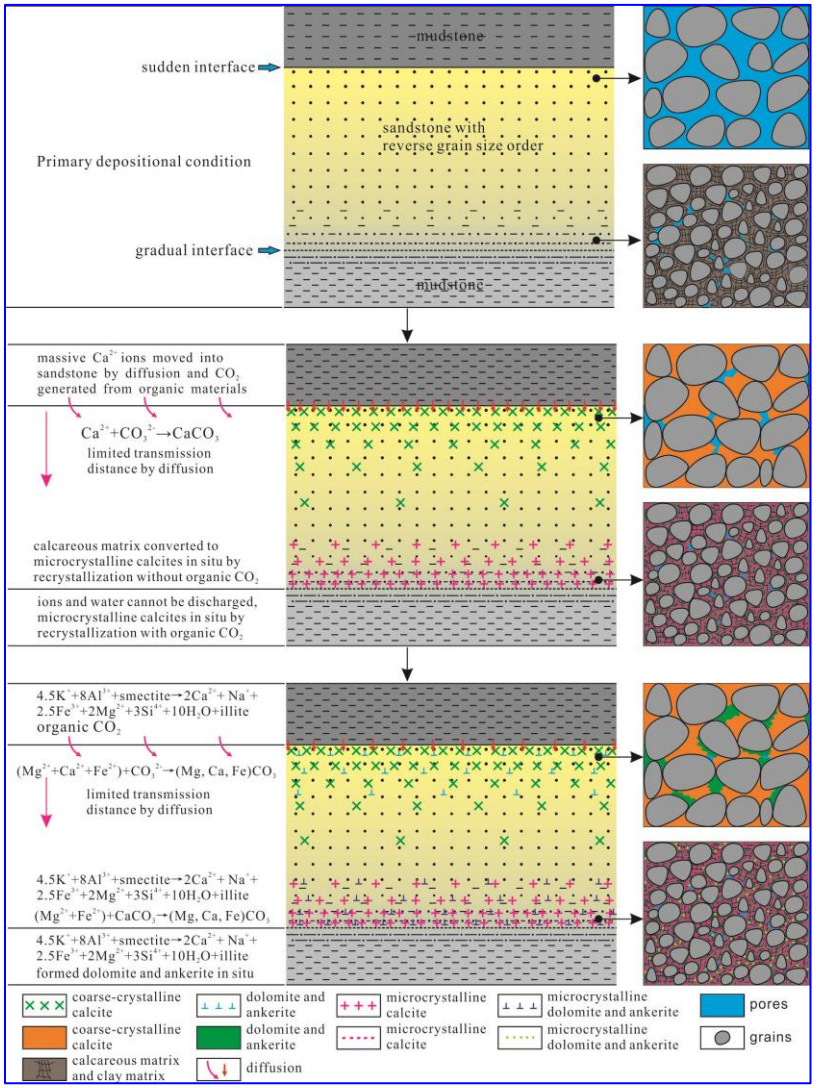
closed geochemical system

Highlight 4

Genetic mechanism of abundant various carbonate cements at the margin of sandstone beds.



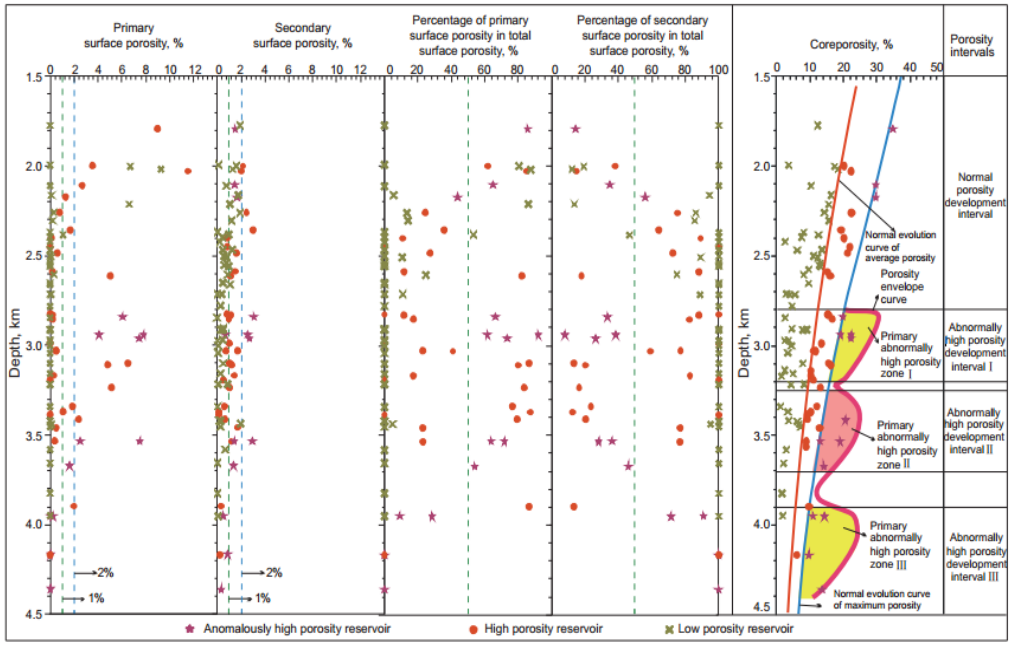


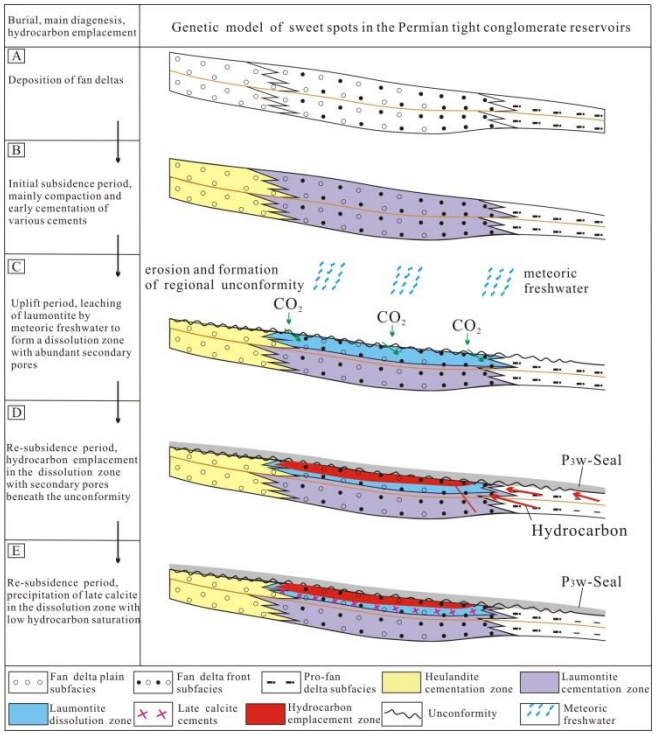


Highlight 5

Genetic models of different types of high quality reservoirs

Types of high quality reservoirs	Fluid overpressure	Hydrocarbon emplacement	Mineral dissolution	grain rims	Geochemical system
Primary pores dominated	√ √ √	√ √	√	√	**Closed**
Redistribution secondary pores dominated	√ √	√ √	√ √	-	**Closed**
Enhanced secondary pores dominated	√	√ √	√ √ √	-	**open**



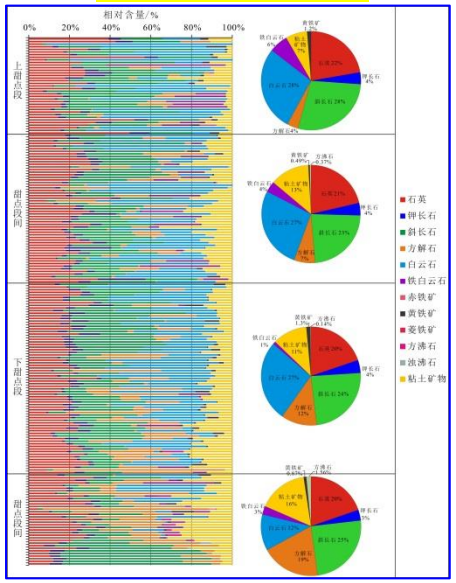


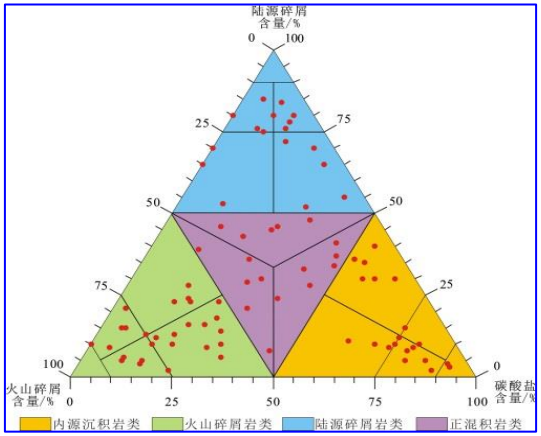
Highlight 6

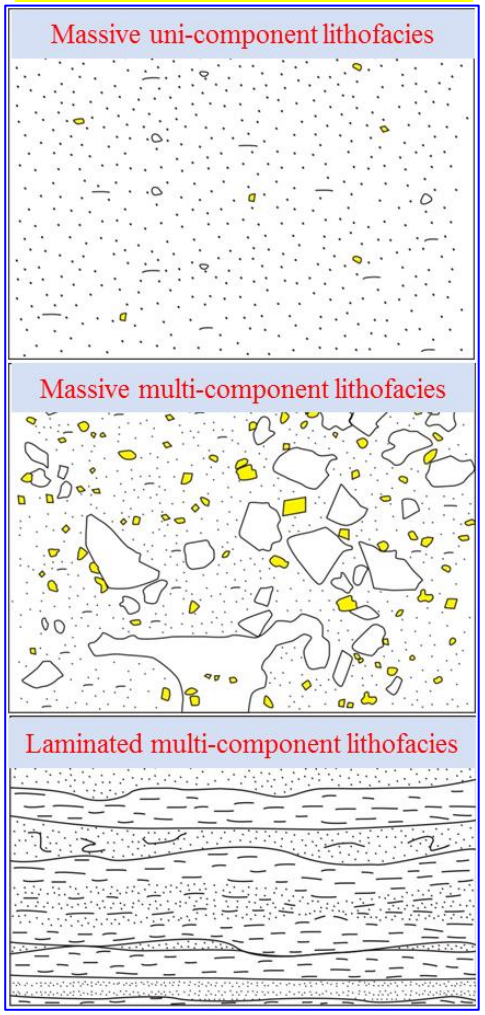
Mixed fine-grained sedimentary rocks

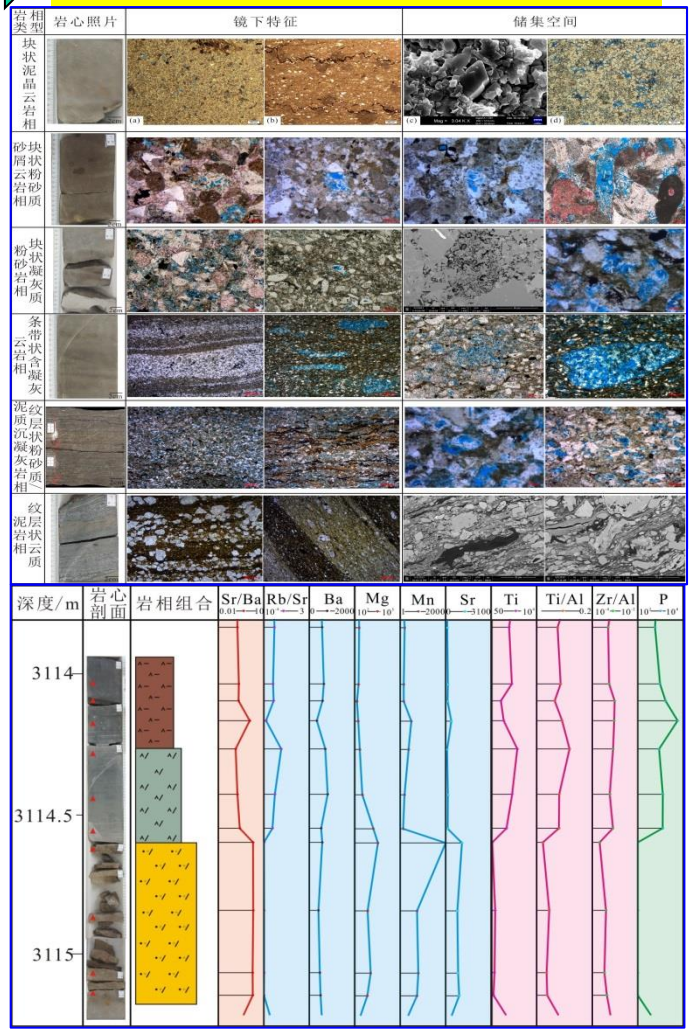
Lithofacies classification of mixed fine-grained rocks and its environment implication

component → **Sedimentary structure** → **Lithofacies and superposition**





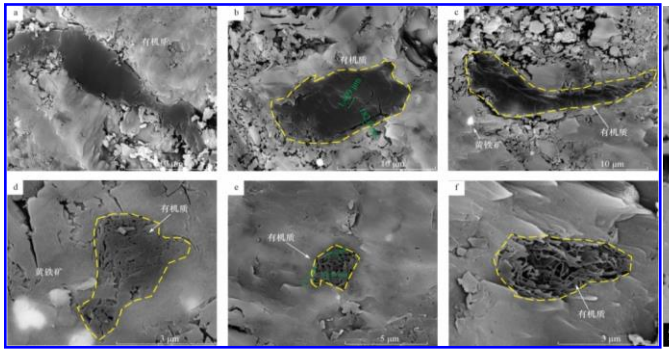


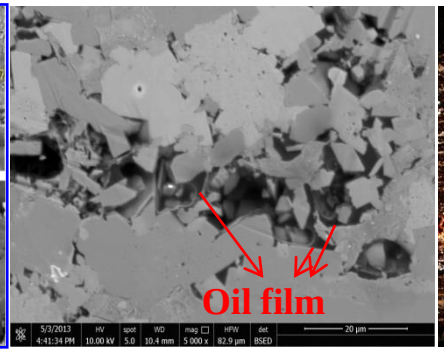


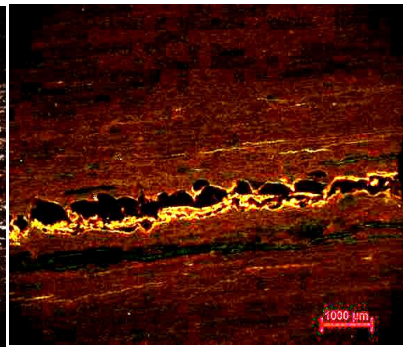
Highlight 6

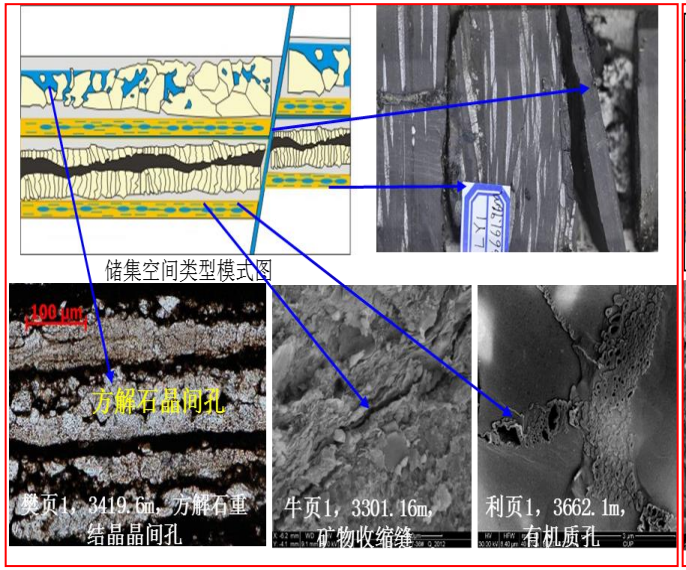
Mixed fine-grained oil and gas reservoir

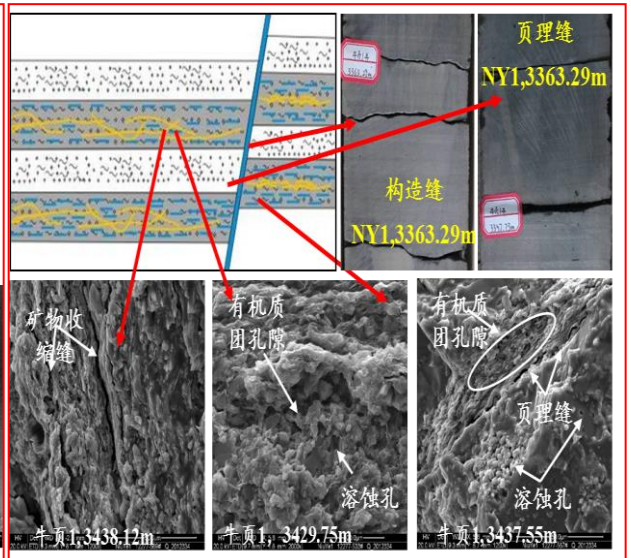
Pore formation and diagenetic evolution + **reservoir wettability of mixed fine-grained rocks** → **oil accumulation and oiliness characteristics**

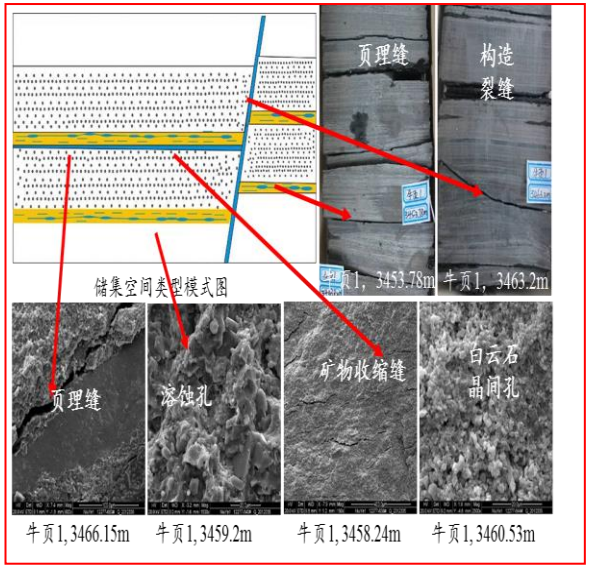












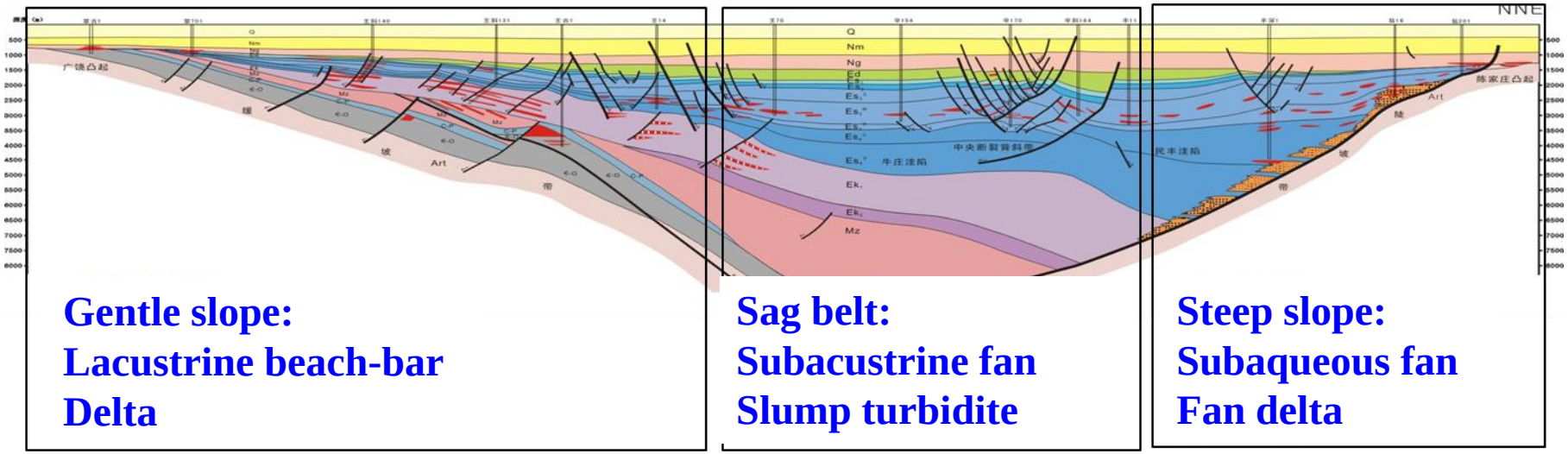
Rich-organic shaly limestone

medium-organic shaly calcareous claystone

Poor-organic shaly limestone

- 1.Introduction
- 2.Research Field
- 3.Research highlights
- 4.Research Key Point

Research key point



Gentle slope:
Lacustrine beach-bar
Delta

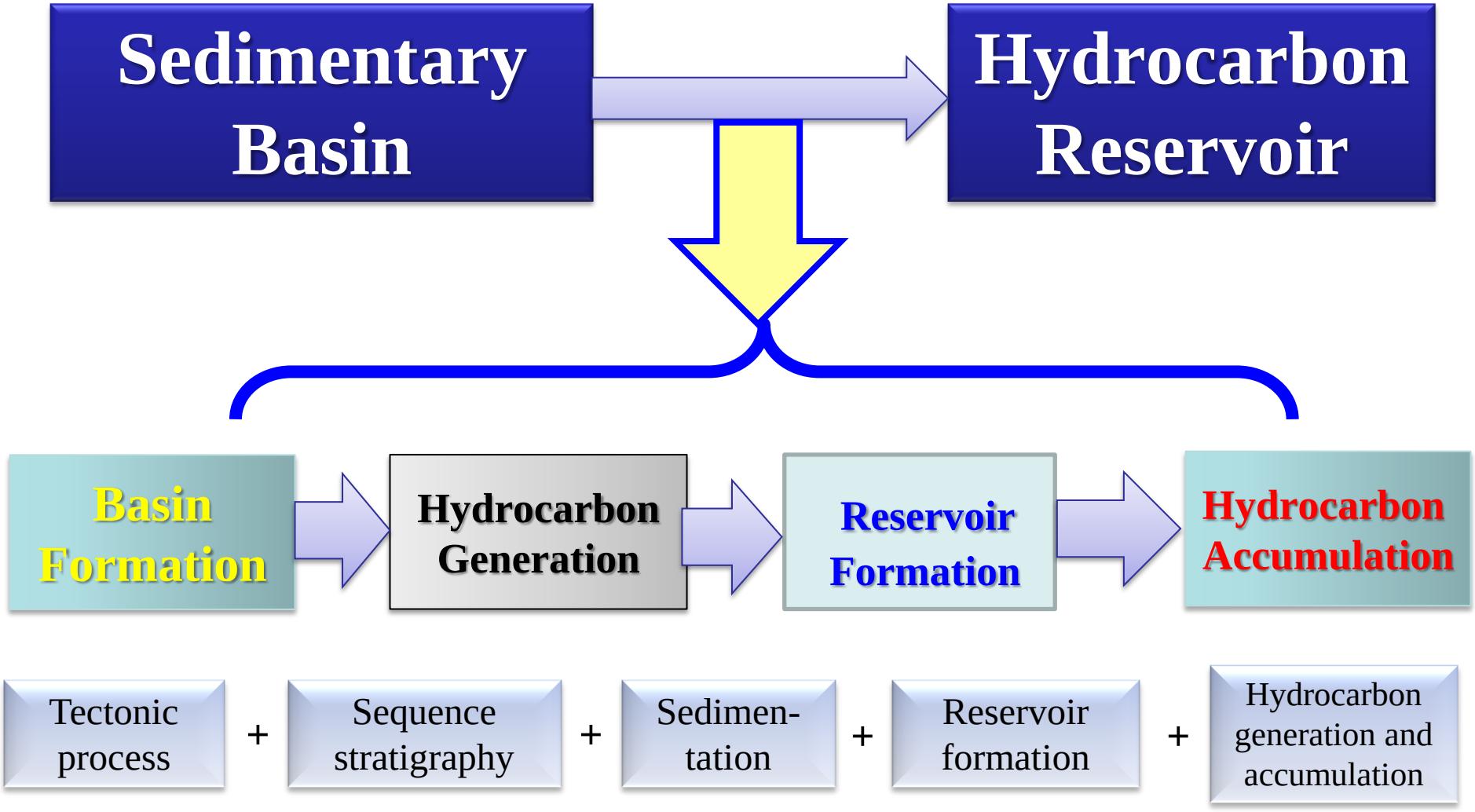
Sag belt:
Subacustrine fan
Slump turbidite

Steep slope:
Subaqueous fan
Fan delta

Source Rocks ⟷ Reservoirs

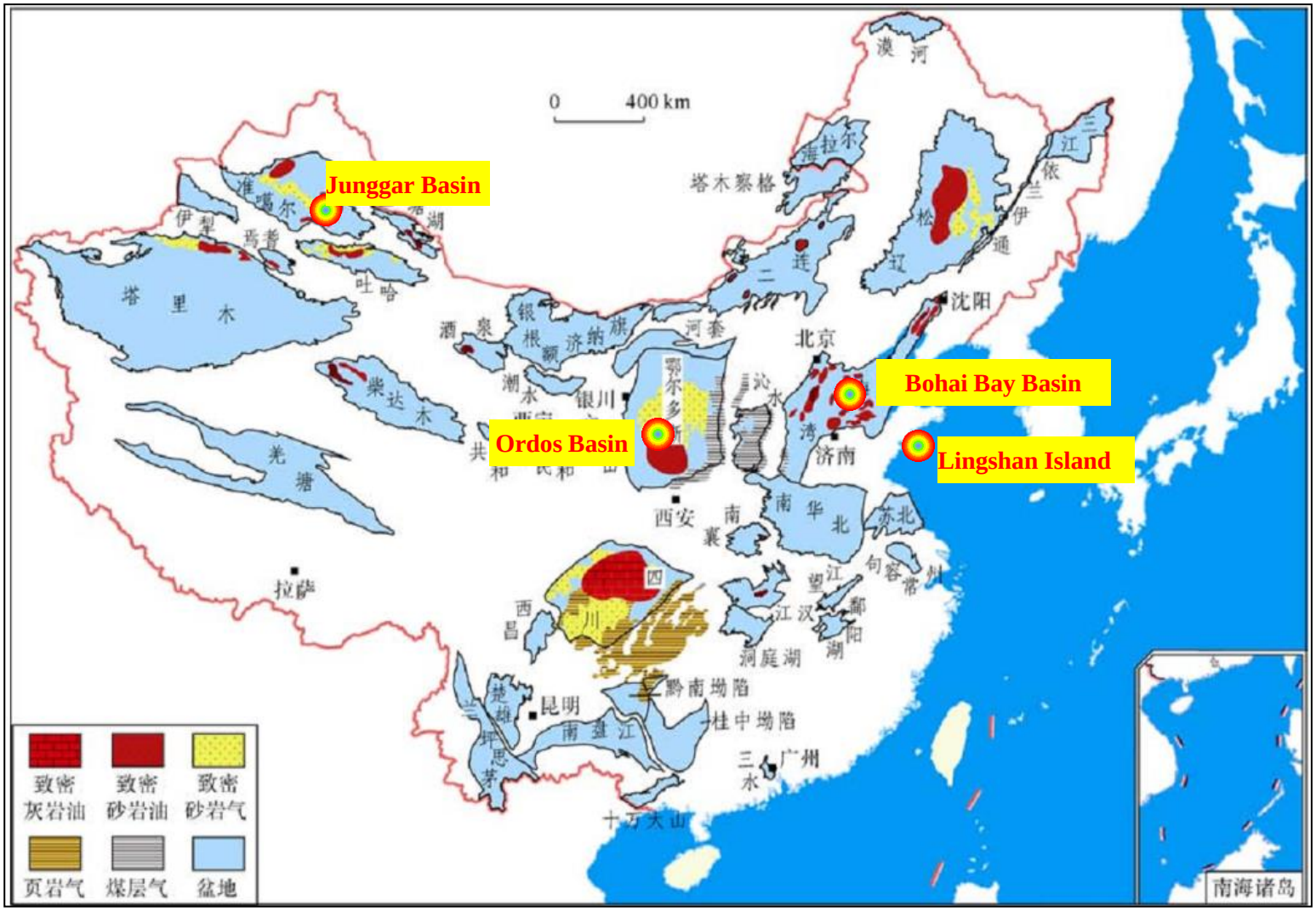
- Source＝Reservoir
- Source≠Reservoir
  - Reservoirs within source rocks
  - Reservoirs interfingered with source rocks
  - Reservoirs seperated from source rocks

Research key point



Integrated Research

Point 1


Junggar Basin
Ordos Basin
Bohai Bay Basin
Lingshan Island
0
400 km
致密灰岩油
致密砂岩油
致密砂岩气
页岩气
煤层气
盆地
南海诸岛

Point 1

Depositional mechanism of fine-grained mixed sedimentary rocks

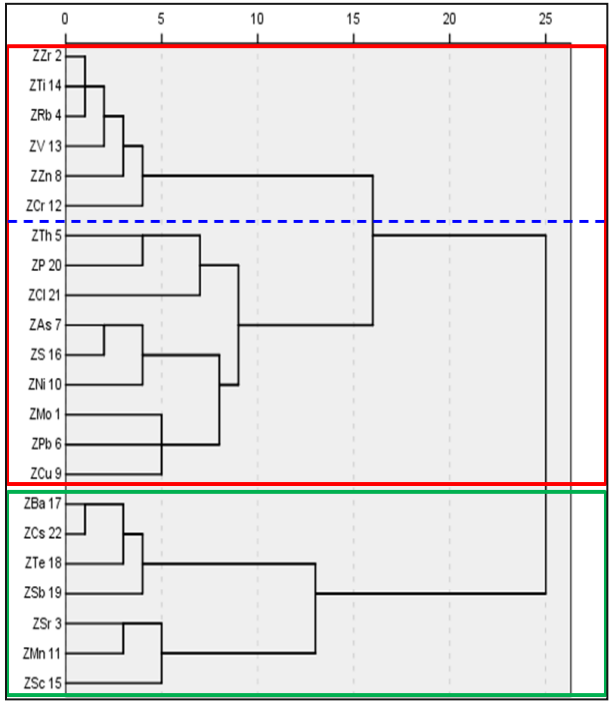
Mineral component
Major and trace element
Well logging data
……

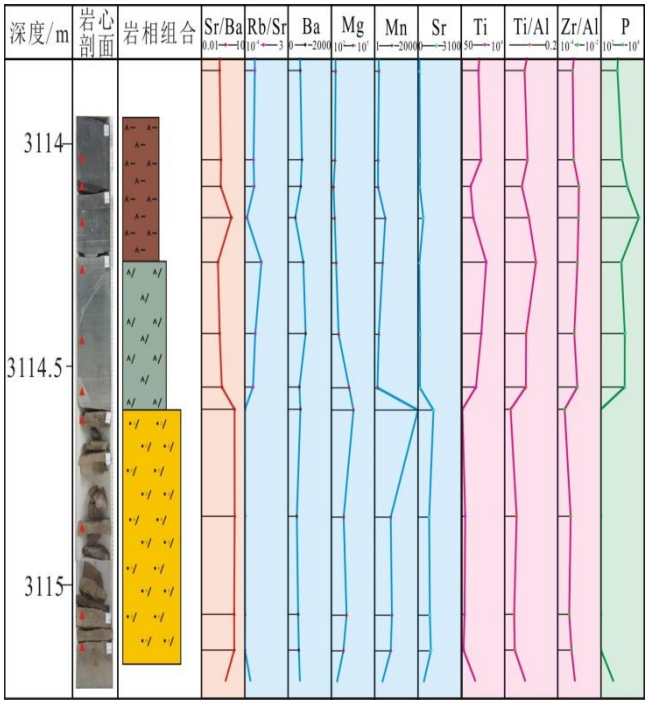
→

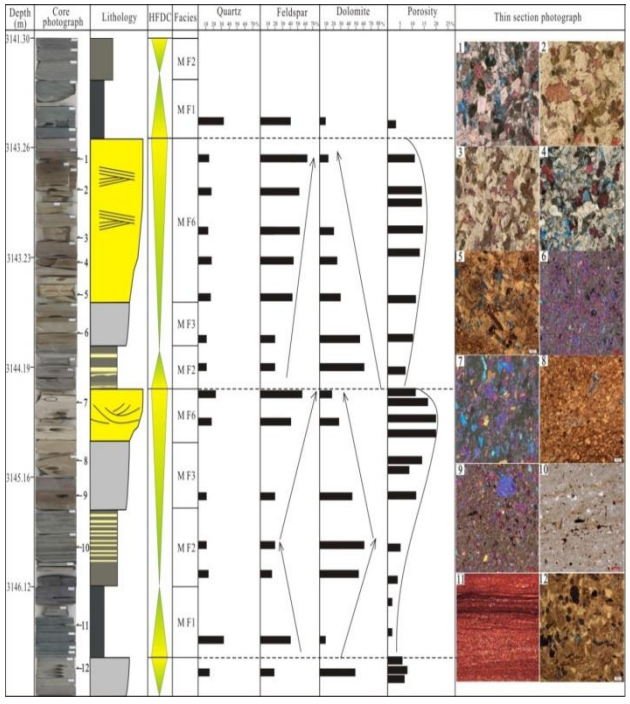
Depositional environment
High-frequency sedimentary cycle

→

Controlling on reservoir quality

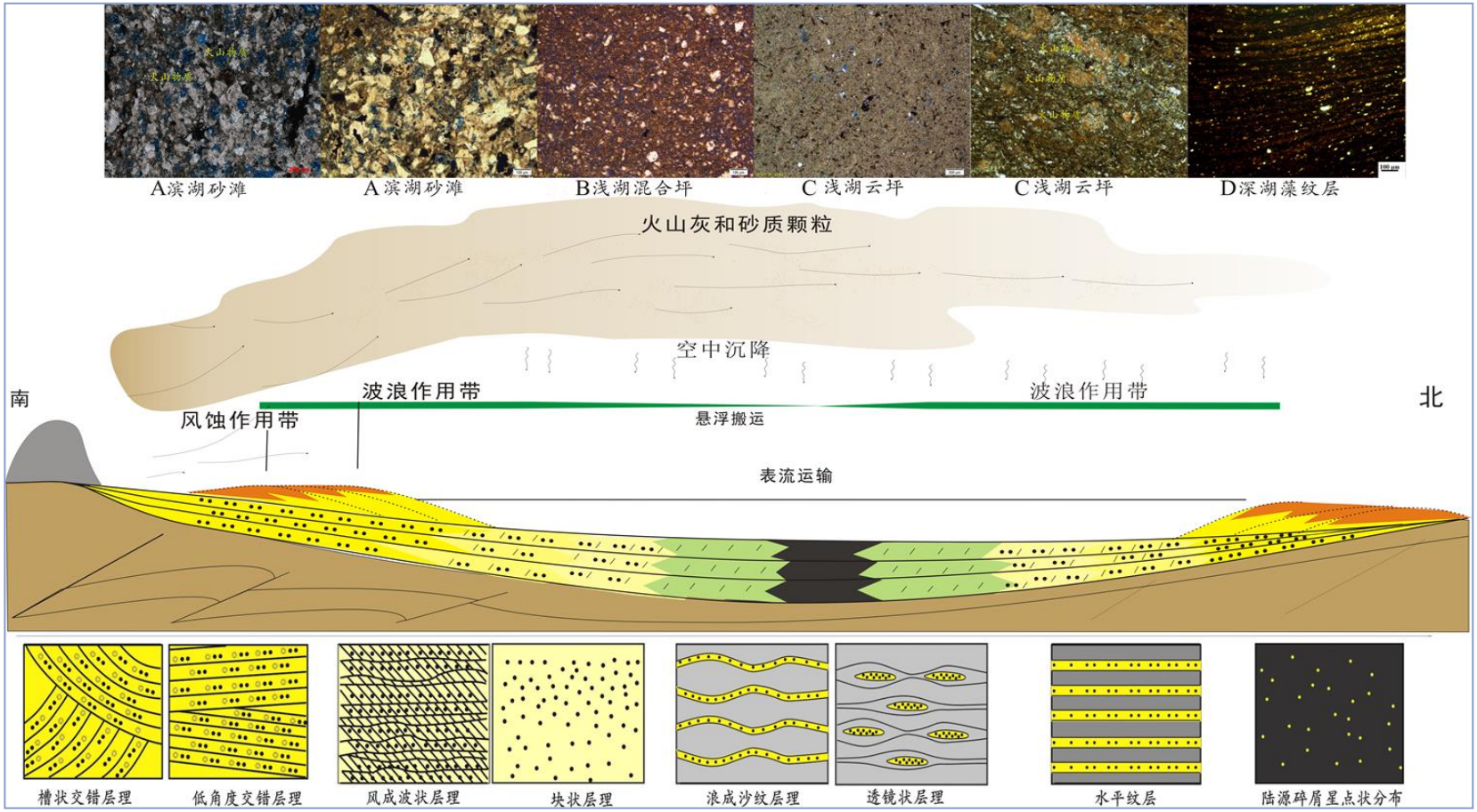






Point 1

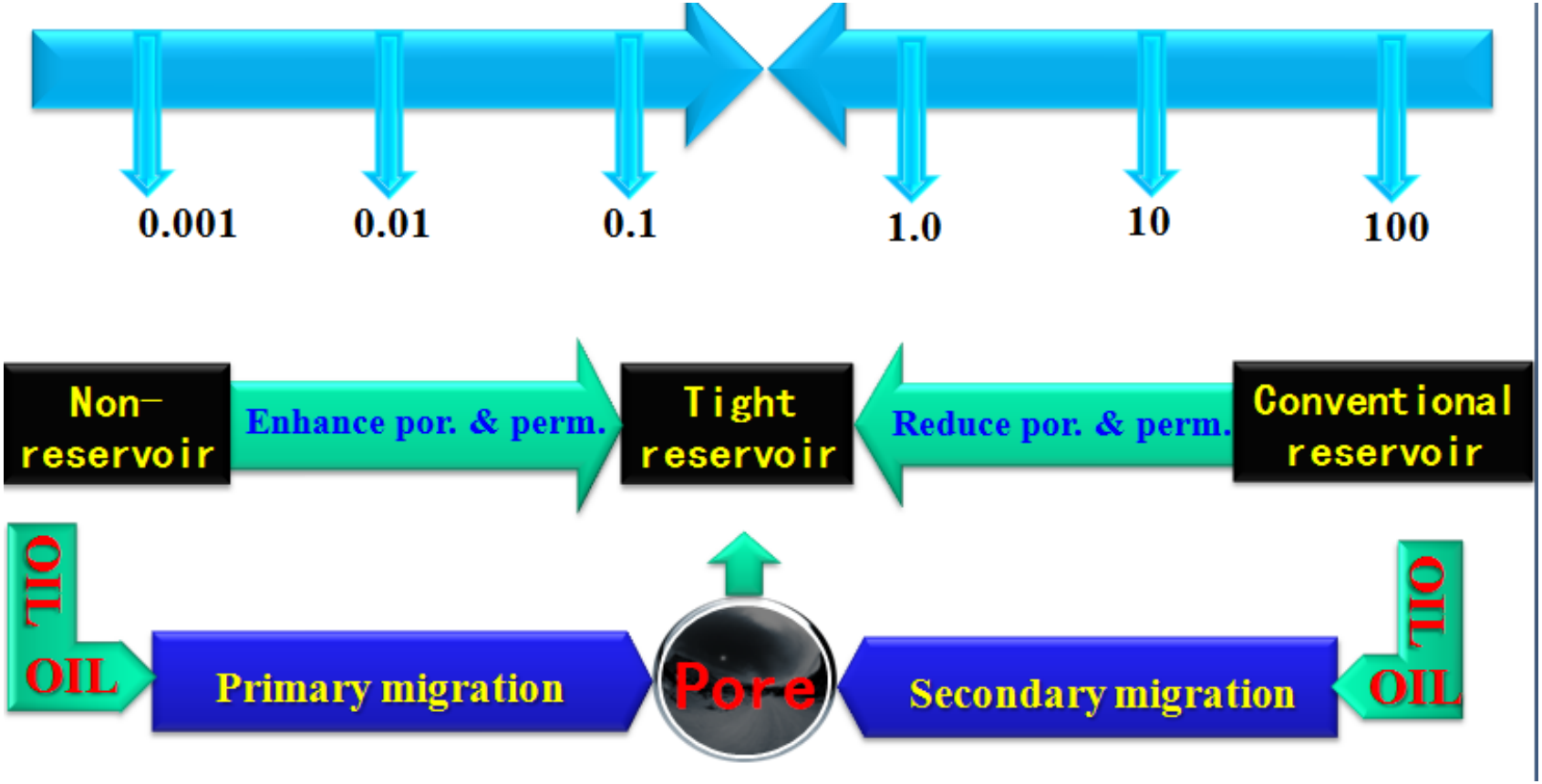
Depositional mechanism of fine-grained mixed sedimentary rocks



sedimentary model of fine-grained mixed-sedimentary rocks in Jimusaer Sag, sediments were transport by wind and deposited in lakes.

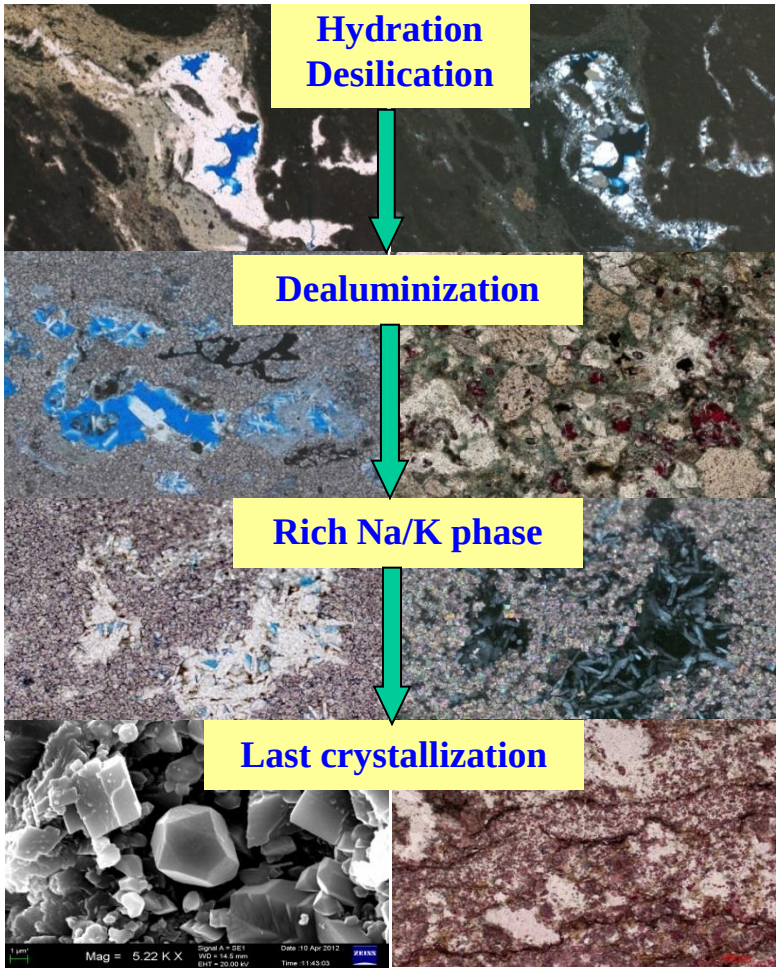
Point 1

Diagnesis and formation of fine-grained tight oil / gas reservoirs

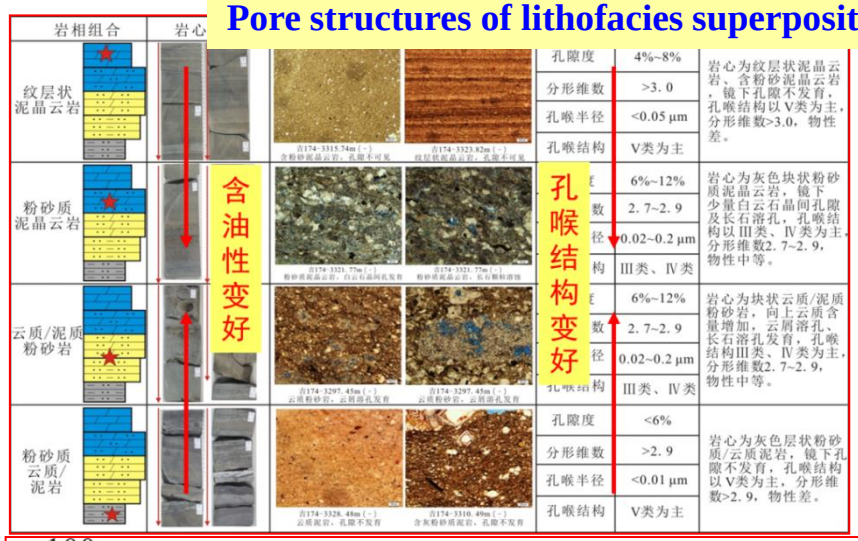


Point 1

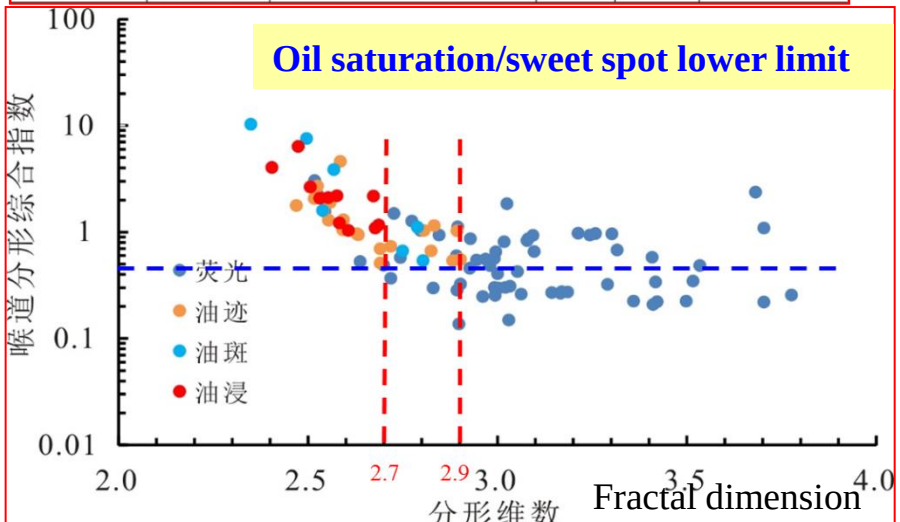
Diagnesis and formation of fine-grained tight oil / gas reservoirs



Pore structures of lithofacies superposition

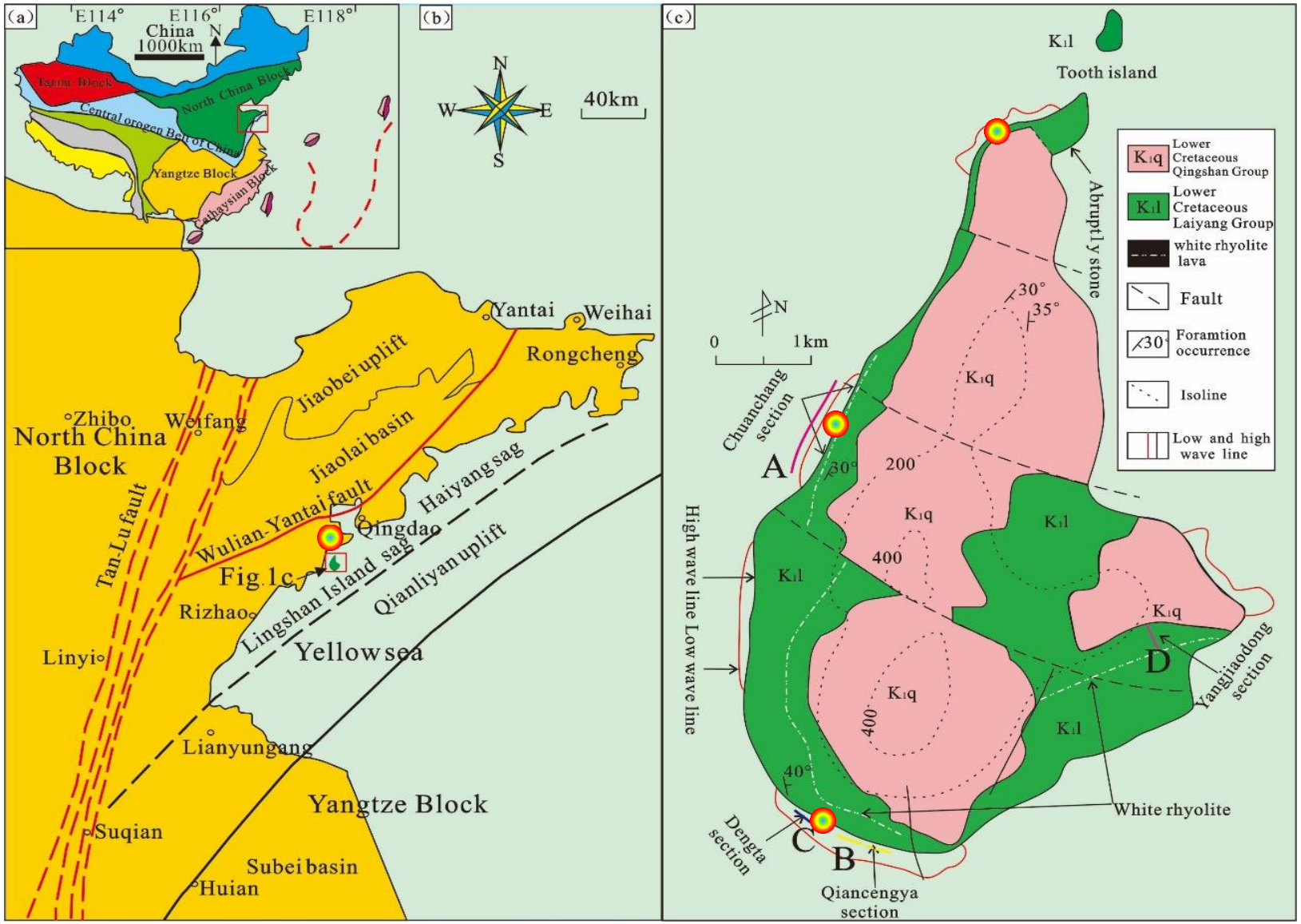


Oil saturation/sweet spot lower limit

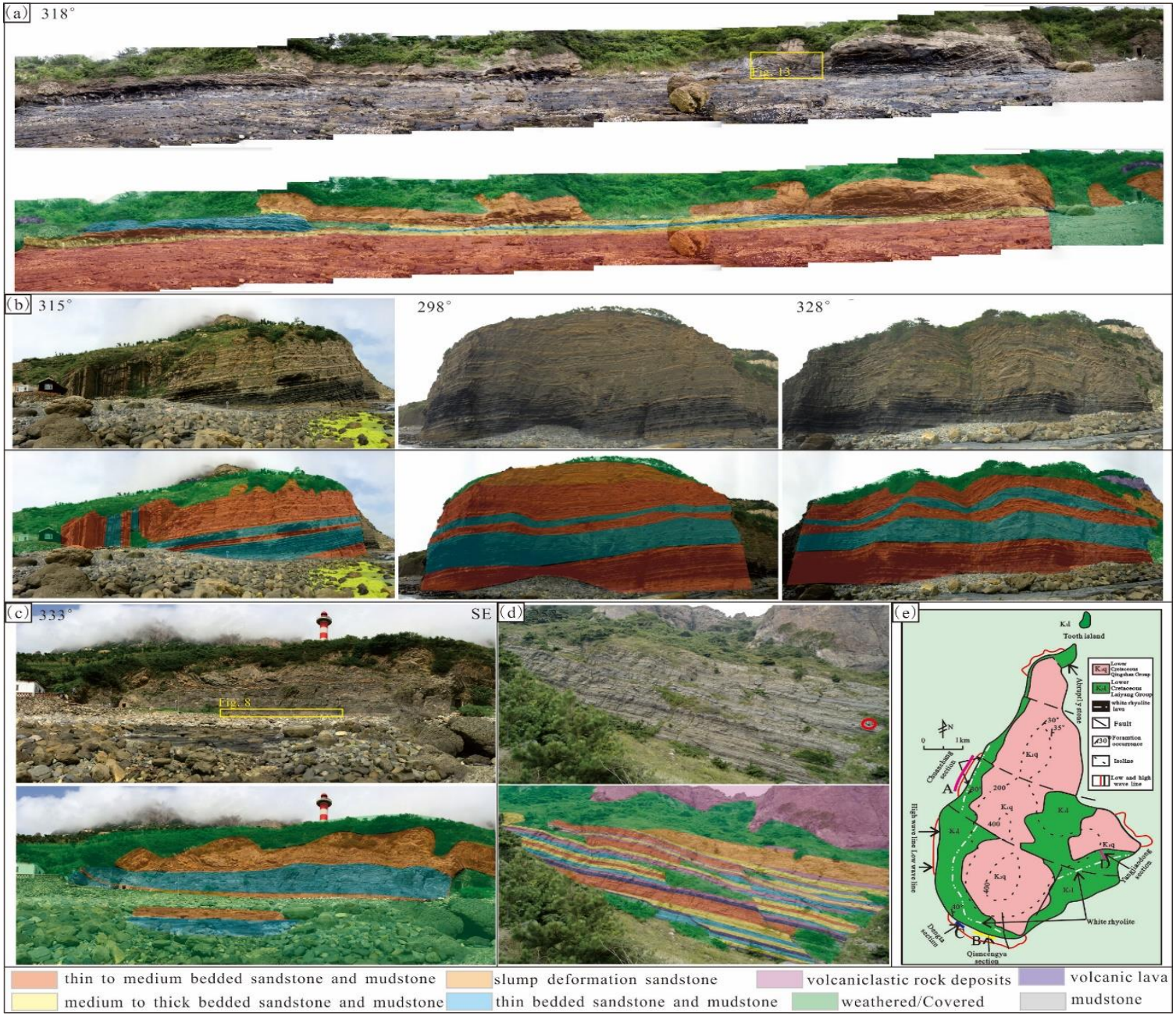


Fractal dimension

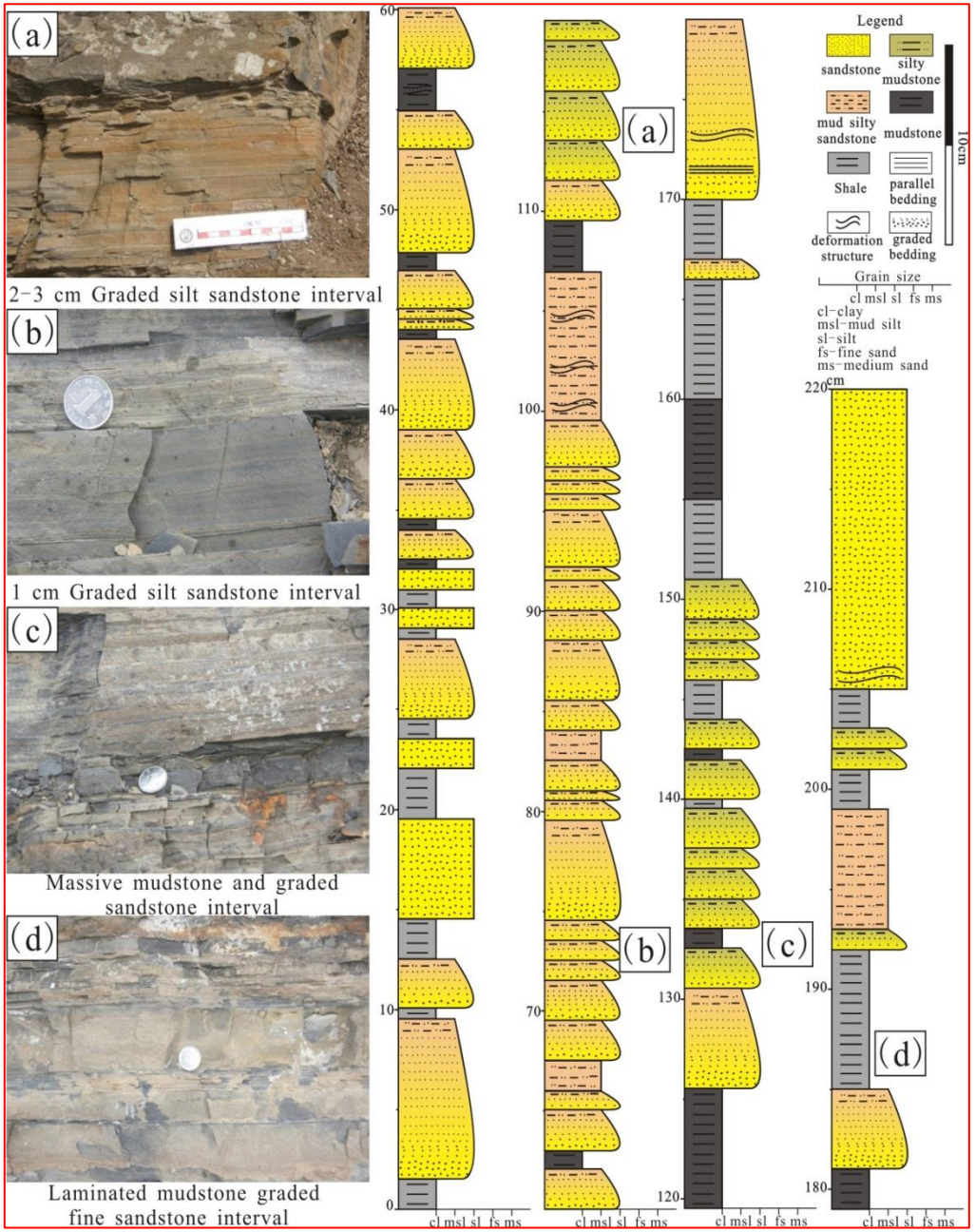
Lingshan island

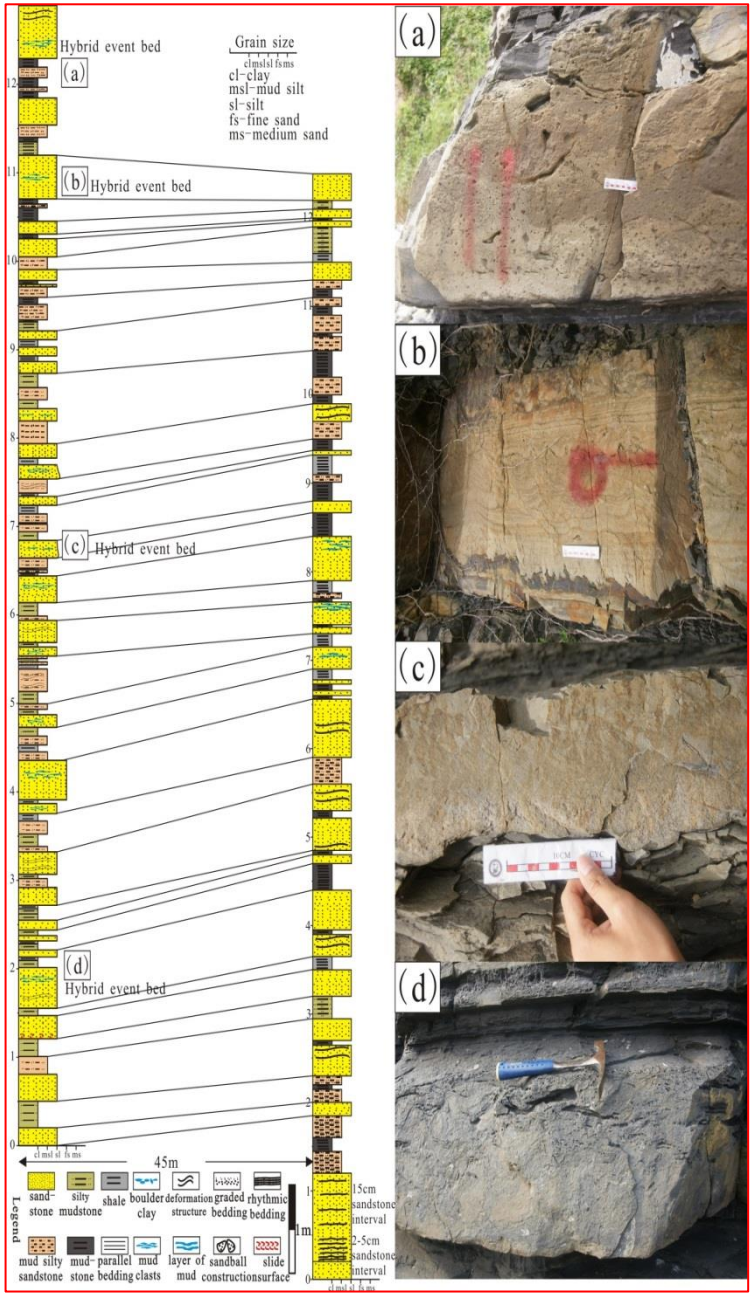


Lingshan island

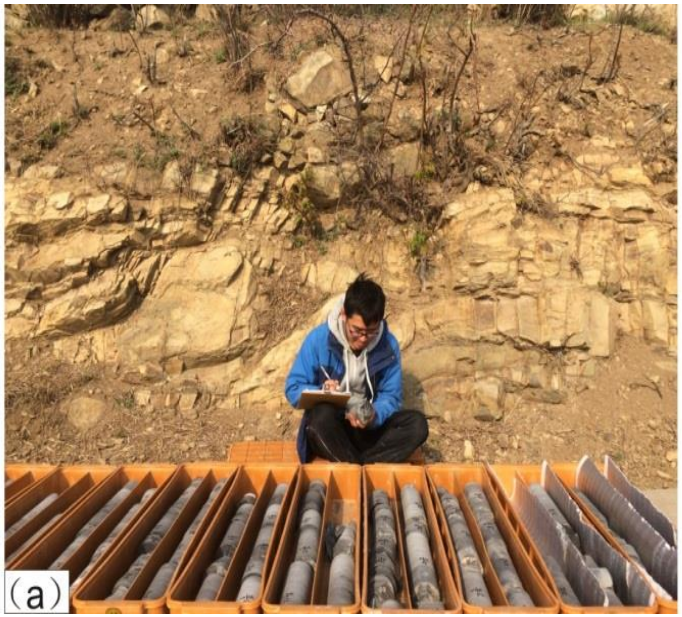


Lingshan island



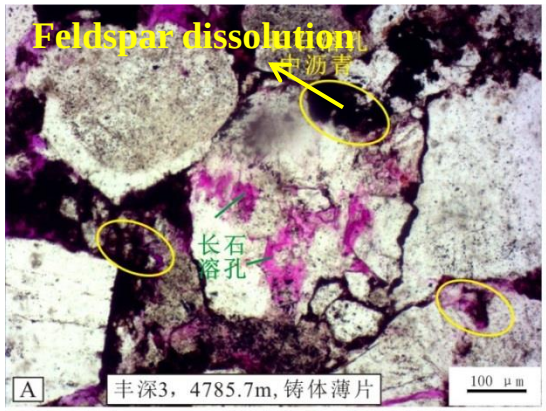


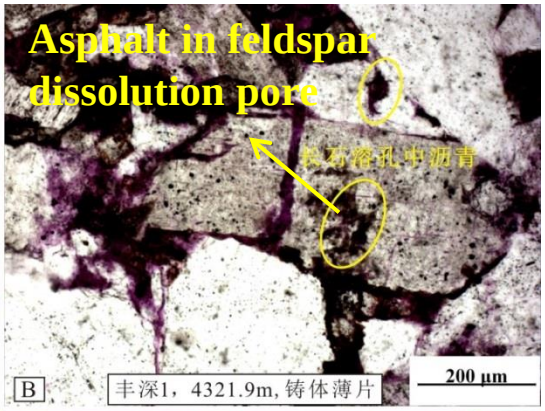
Lingshan island

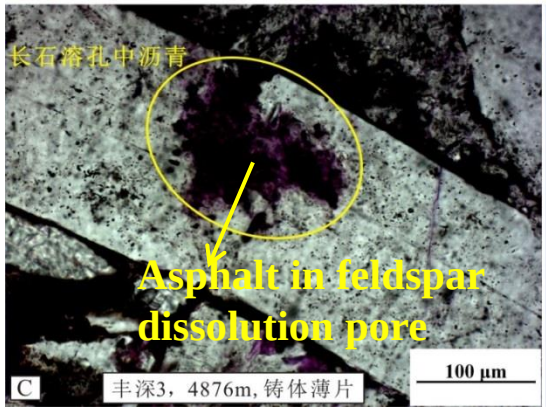


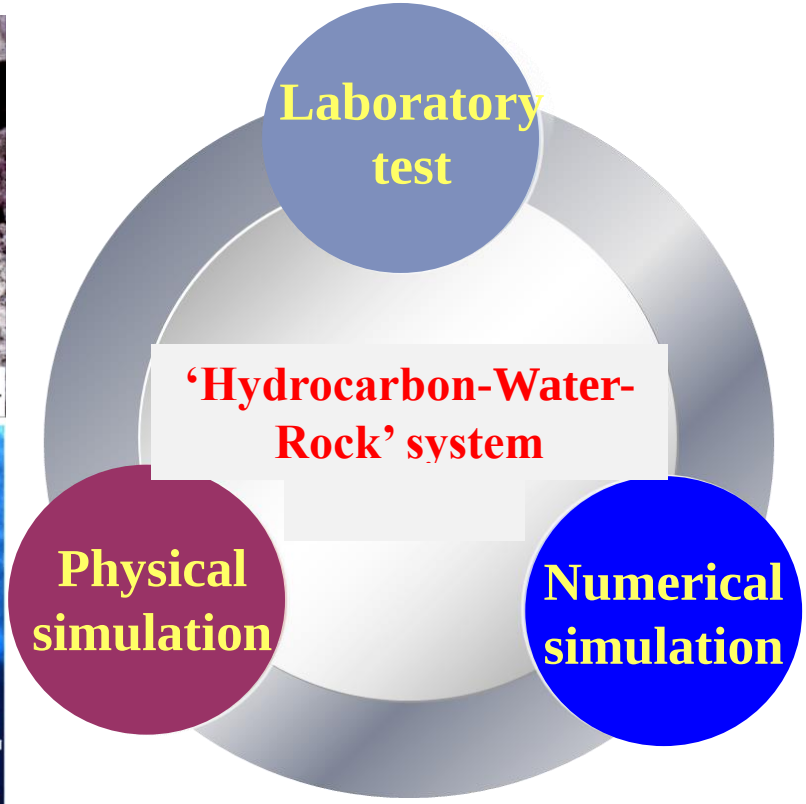
Point 2

Organic-inorganic diagenesis



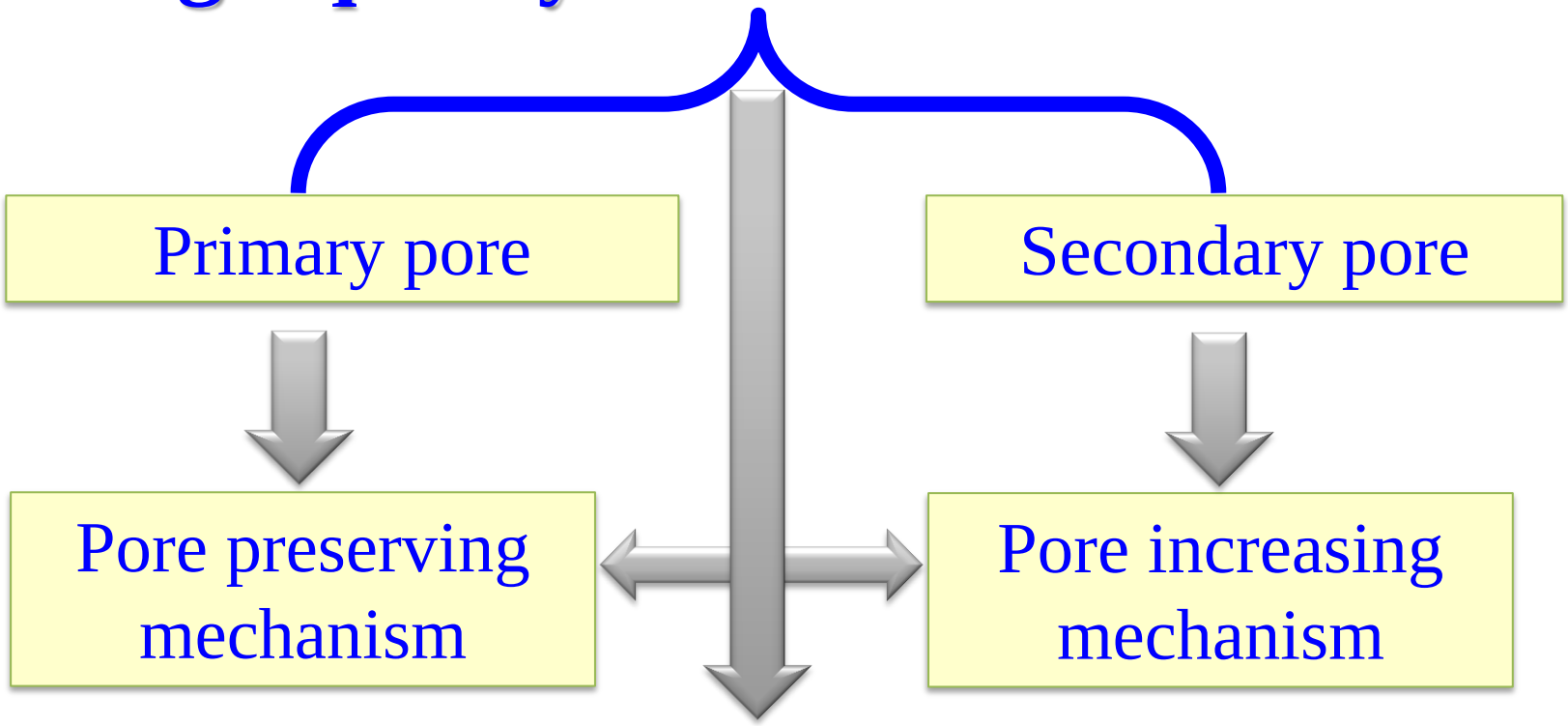






Point 3

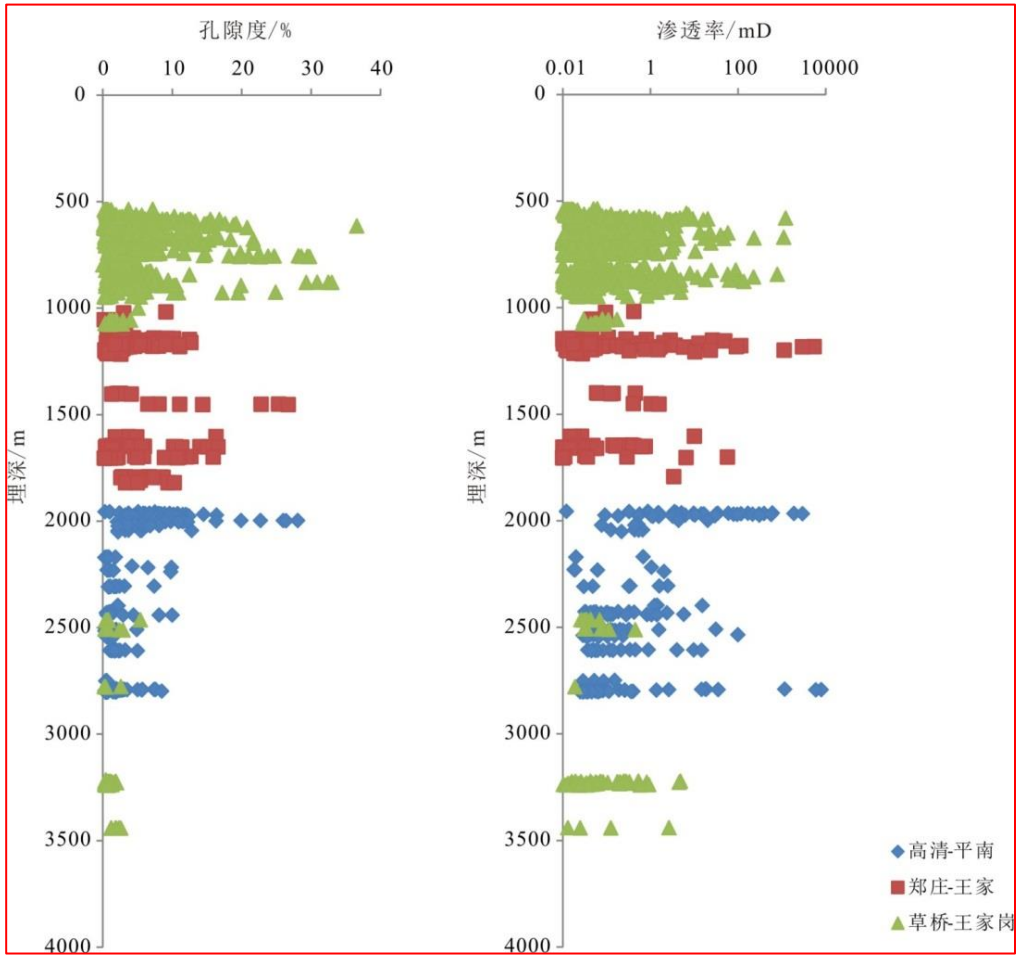
Genesis of ultra-deeply buried high-quality sandstone reservoirs

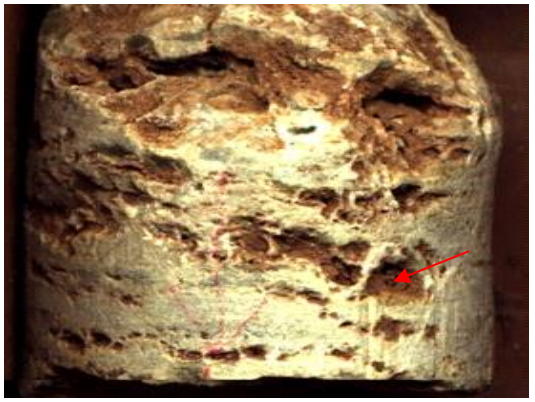


Quantitative diagenesis and origin of ultra-deeply buried high quality reservoirs within source rock - reservoir geochemical systems

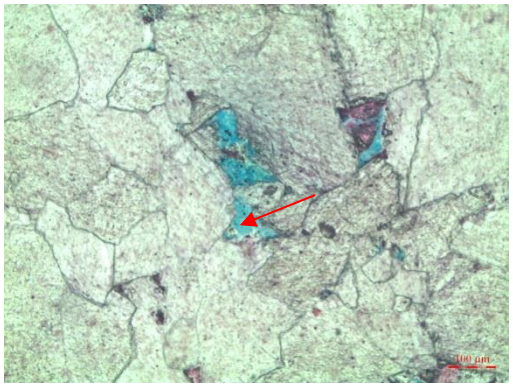
Point 4

Reality of burial mesogenetic dissolution in carbonate rocks





Caogu130, 717.3m, secondary pores



Bingu301, 2044.39m， secondary pores

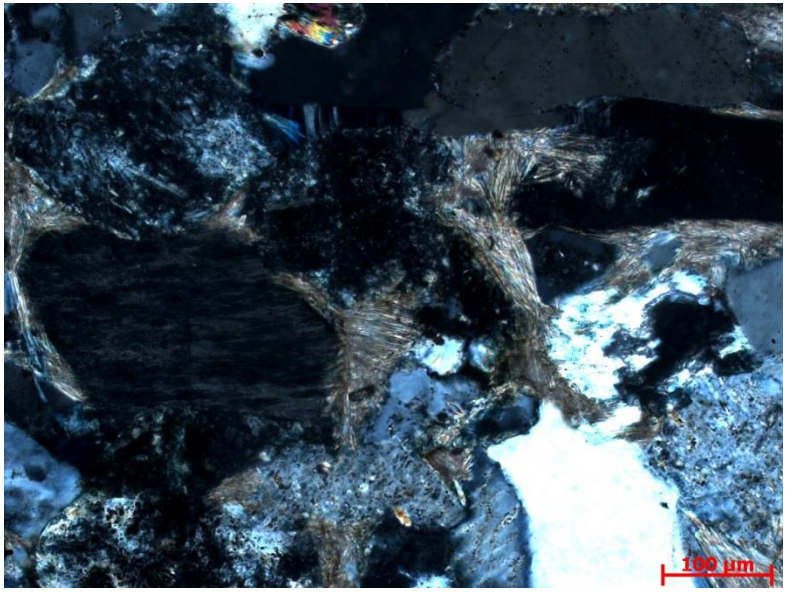
Point 5

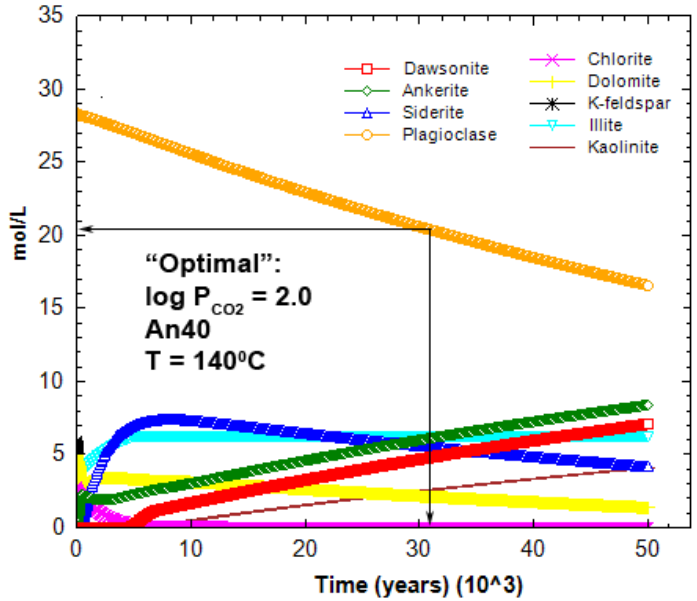
CO_2 storage and Environmental Geology

CO_2 → Carbonate minerals

↓

Mineral carbonatization





Point 6

Petroleum Reservoir Construction & Evolution Simulation System （PROCESS）

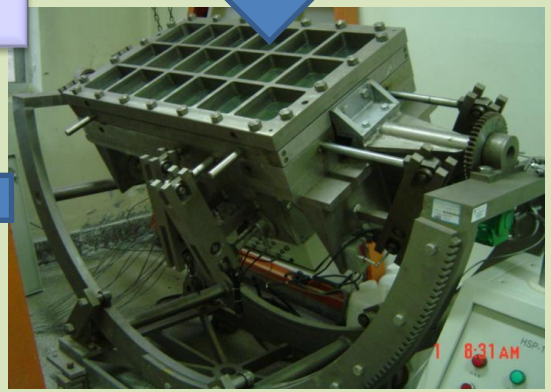
Physical Simulation System

Sedimentary simulation—sandbodies

Diagenetic simulation—reservoirs

4D Seismic monitoring

Development simulation
Residual petroleum distribution

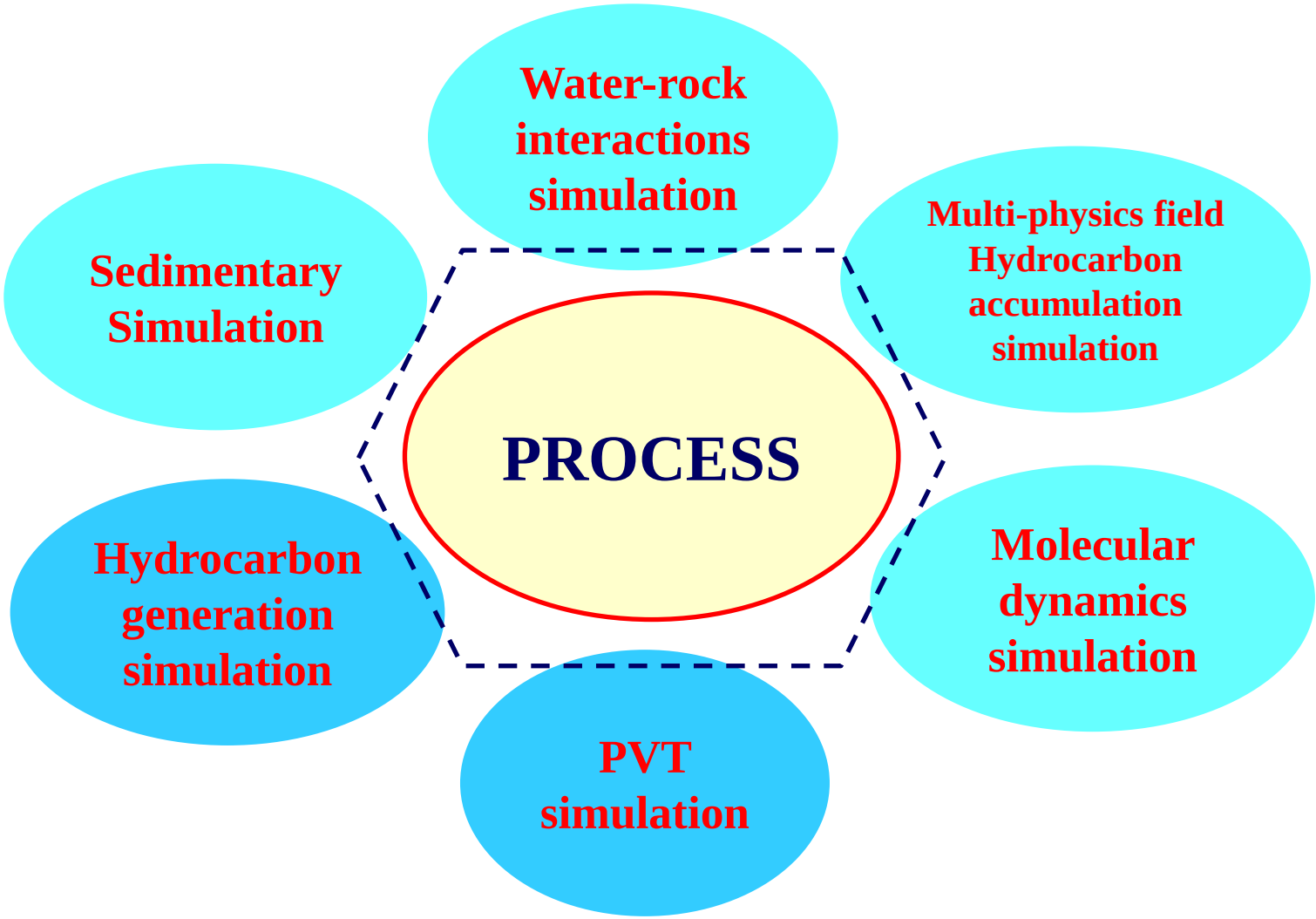


Migration simulation—
Hydrocarbon emplacement

Point 6

Petroleum Reservoir Construction & Evolution Simulation System （PROCESS）

Numerical Simulation System



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Thank you !

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Petroleum reservoir research center