Major Geological Properties of Sedimentary Basin and Related Technical Challenges for CO_2 Aquifer Storage in China

中国主要地质特点及其对CO_2咸水层封存的技术挑战

Ning Wei 魏宁

Institute of Rock and Soil Mechanics, Chinese Academy of Sciences

Outline

- ➢ **Background of CO_2 geological storage**
- ✓ CO_2地质封存背景
- ➢ **Major geological setting of sedimentary basins in China**
- ✓ 中国沉积盆地的主要地质特点
- ➢ **Major technical challenges related to geological setting**
- ✓ 地质特征导致的主要技术挑战
- ➢ **The possible solution to the technical challenges**
- ✓ 可能的解决策略
- ➢ **Summary**
- ✓ 结论

Background of CO_2 geological storage

CCS system

CO_2 emission sources

Pipeline

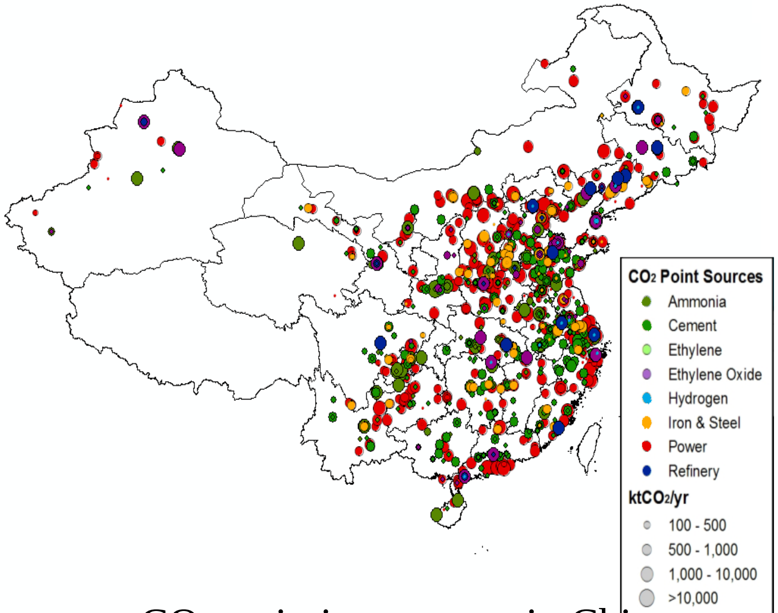
Injection facility of aquifer storage

CO_2 capture+ compression +transportation (pipeline) + geological storage （Aquifer storage)

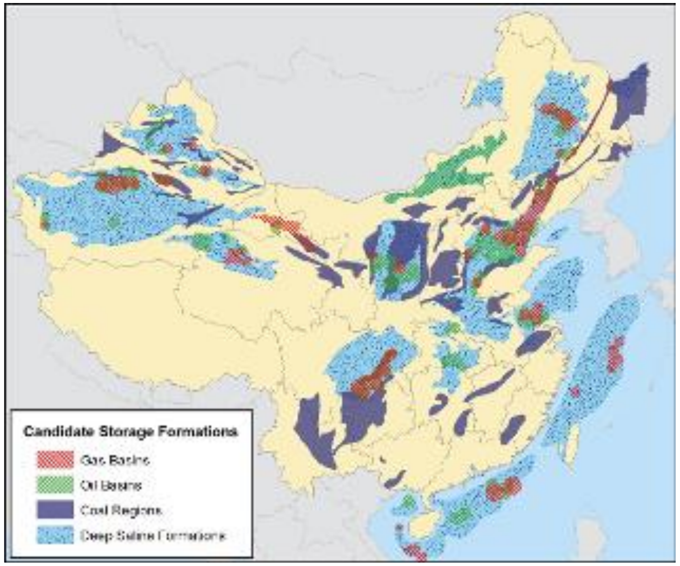
CO_2 捕集+ 压缩 +管道运输 + 封存场地（咸水层封存）

Background of CO_2 geological storage

CO_2 emission sources and storage capacity in China



CO_2 emission sources in China



Potential storage Sites in China

Total estimated CO_2 geological storage capacity (basin scale theoretical capacity)

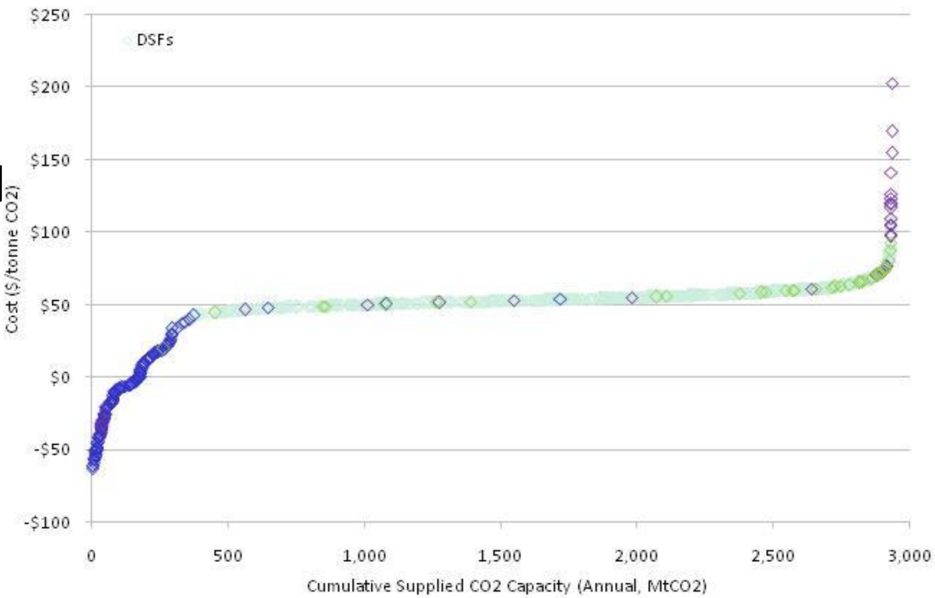
	Total estimated capacity ($MtCO_2$)	Estimated capacity in oilfields by proved OOIP($MtCO_2$)	Estimated capacity in gas fields by proved OGIP($MtCO_2$)	Estimated Capacity in un-mineable coalbed ($MtCO_2$)	Estimated Capacity in deep saline formation ($MtCO_2$)
Onshore	2,380,000	4,600	4,280	12,000	2,280,000
Total	3,088,000	4,800	5,180	12,000	3,066,000

Li, Wei, Dahowski, et al, 2012

Background of CO_2 geological storage

Preliminary results of sources-sinks matching for China

- There are a number of potential opportunities for low and even negative cost storage options;
- 低成本的CCS技术早期机遇；
- The vast majority of storage potential is offered by the large and high capacity deep saline formations at estimated transport and storage costs of less than \$10/tCO_2 (without capture)
- 大多数CCS项目的运输与封存成本低于10US\$(不含捕集成本)
- However, the properties of geological formation impacts the storage process dramatically, including the technical and cost aspect, further work should be done.



Dahowski, Li et al, 2012

Outline

- ➢ Background of CO_2 geological storage
- ✓ CO_2地质封存背景
- ➢ **Major characteristics of geological formation in China**
- ✓ 中国CO_2地质结构的主要特点
- ➢ Technical challenges for CO_2 geological storage in China
- ✓ CCUS技术实施的主要技术障碍
- ➢ The possible solution to the technical challenges
- ✓ 可能的解决策略
- ➢ Summary
- ✓ 结论

Major geological setting of Chinese Basin

The basic features of sedimentary basins in China

Faults system (multi-scale faults including active faults and field scale faults)
"Walled basin" landform
Complex migration of geo-fluid
Short distance transport of debris- fluvial-lacustrine environments
Late stage reformation
……

Landform - basins are surrounded by mountains or valleys
Multi-cycled - tectonic, sedimentary and stratigraphy sequence rhythm
Sedimentary rate varies with spatial and temporal scale
Sedimentary center varies with time
Pressure build-up
In-situ stress - complex stress field and fractures system;

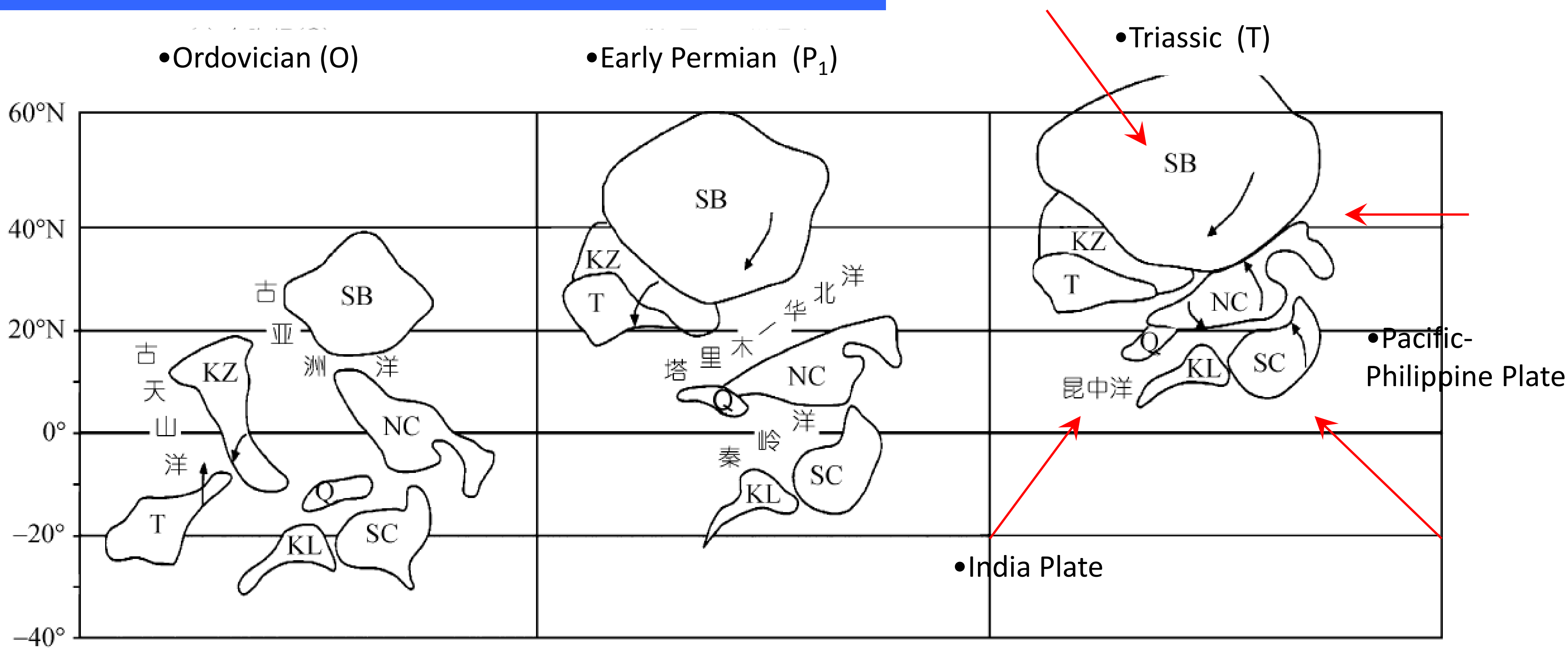
Strong tectonic activity

Active deep action

强烈的构造运动和深部活动是中国沉积盆地的两个最基本的特征，由此带来了中国沉积盆地（封存场地）的一系列特征 (戴金星，2010）

Major geological setting of Chinese Basin

Unique feature of Sedimentary Basins in China

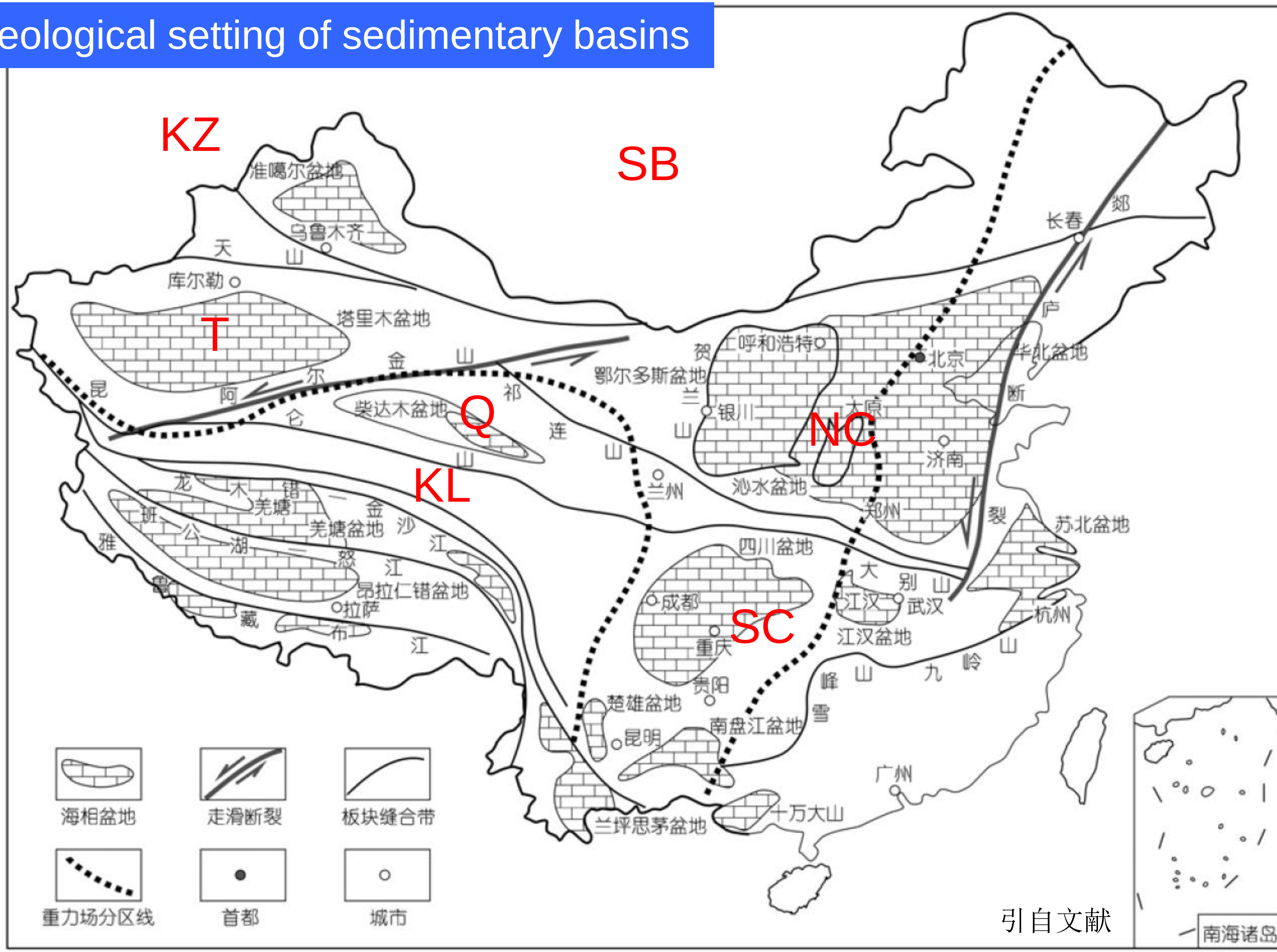


•SB Siberian Block; T Tarim block; Q Qaidam Block; KL Kunlun Block; SC YangZhi Block; NC North China Block

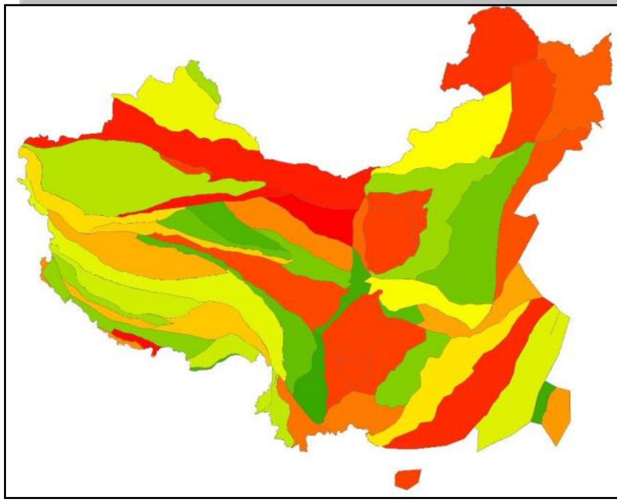
三叠纪时期左右，多个小板块拼合块成中国大陆 (依据板块理论，李德生 ,2002)

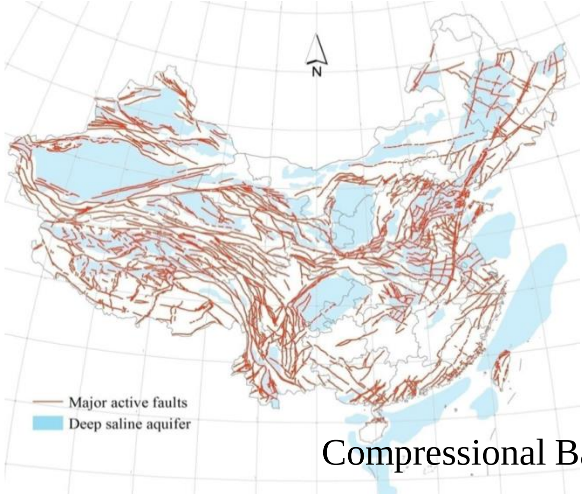
Major geological setting of Chinese Basin

Geological setting of sedimentary basins

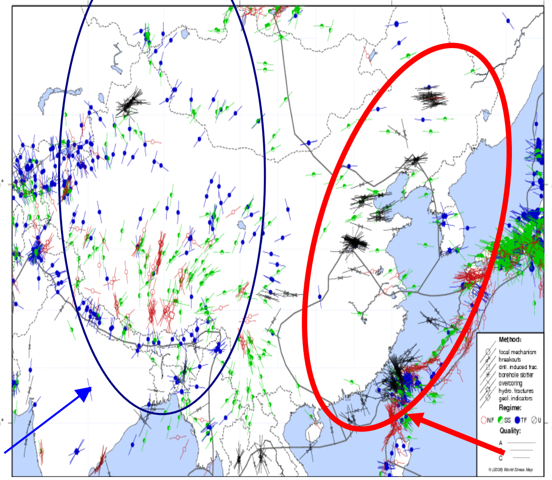


Major geological setting of Chinese Basin



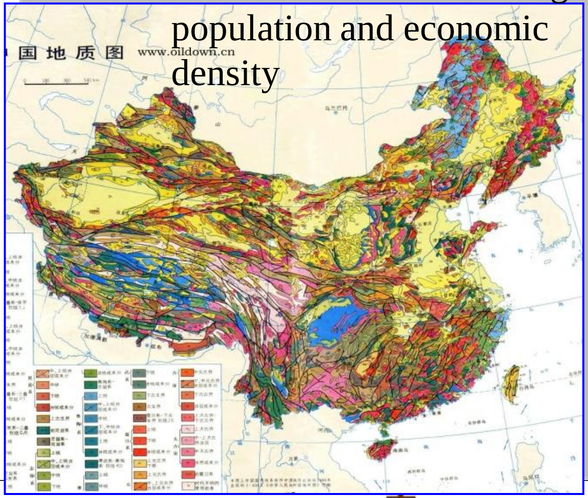


In-situ stress in China



Compressional Basin

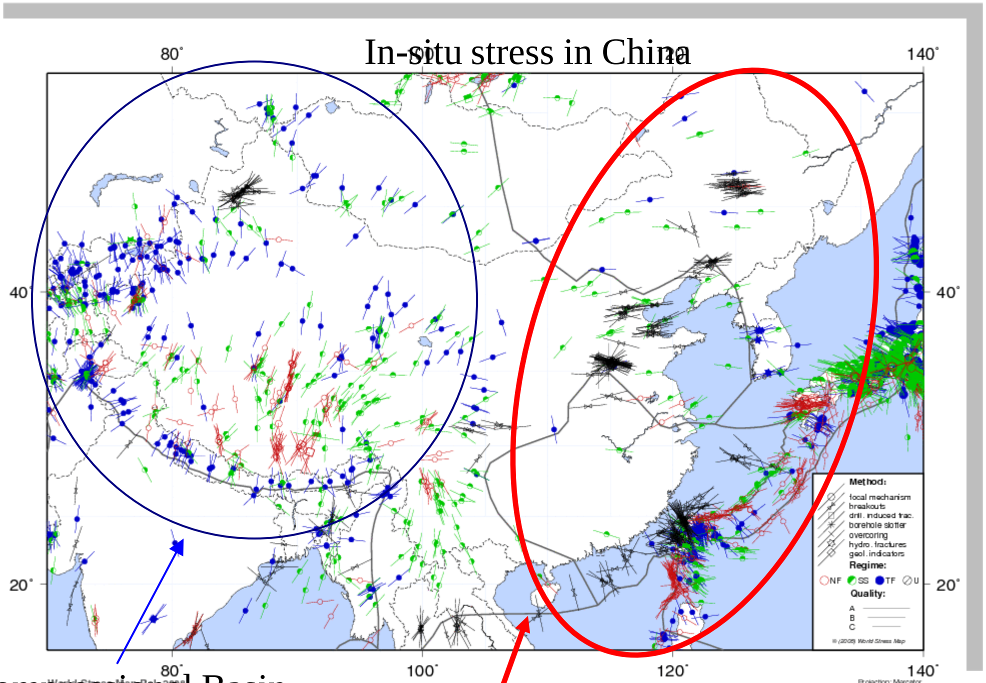
Extensional basin with high population and economic density



1. Tectonic activity 构造活动
- Small tectonic units and basins
- 构造单元较小、盆地规模较小;
- Segmented by major faults
- 部分盆地被主断层密集分割;
- Complex in-situ stress
- 地应力条件复杂
- The stability of geo-mechanics
- 力学稳定性因素对选址、封存量评估、封存控制很重要。

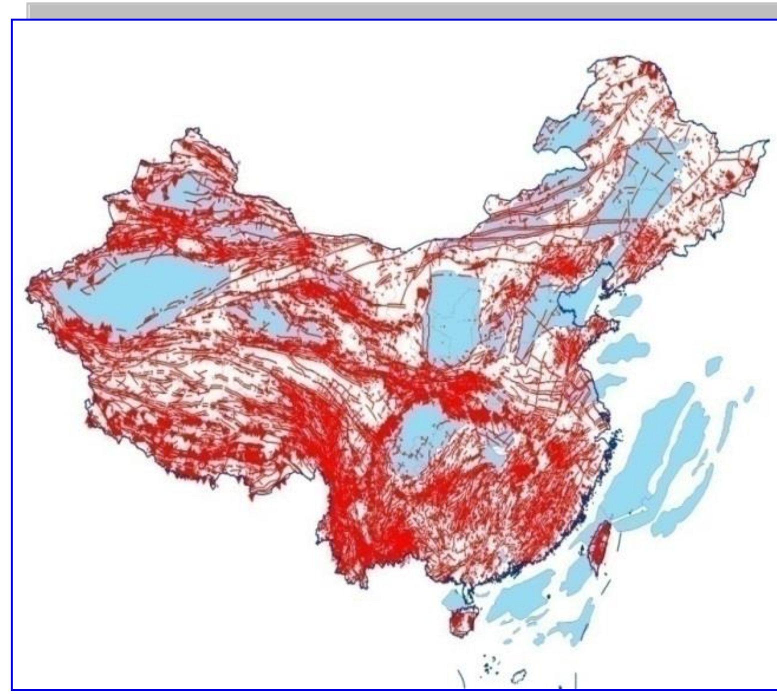
Major geological setting of Chinese Basin

The geological characteristics of Chinese sedimentary basin is very complex.



Compressional Basin

Extensional basin with high population and economic density



地质结构的复杂特征增加了中国实施CO_2地质封存的技术难度与不确定性

The complexity of geological setting increases the uncertainty of CO_2 geological storage

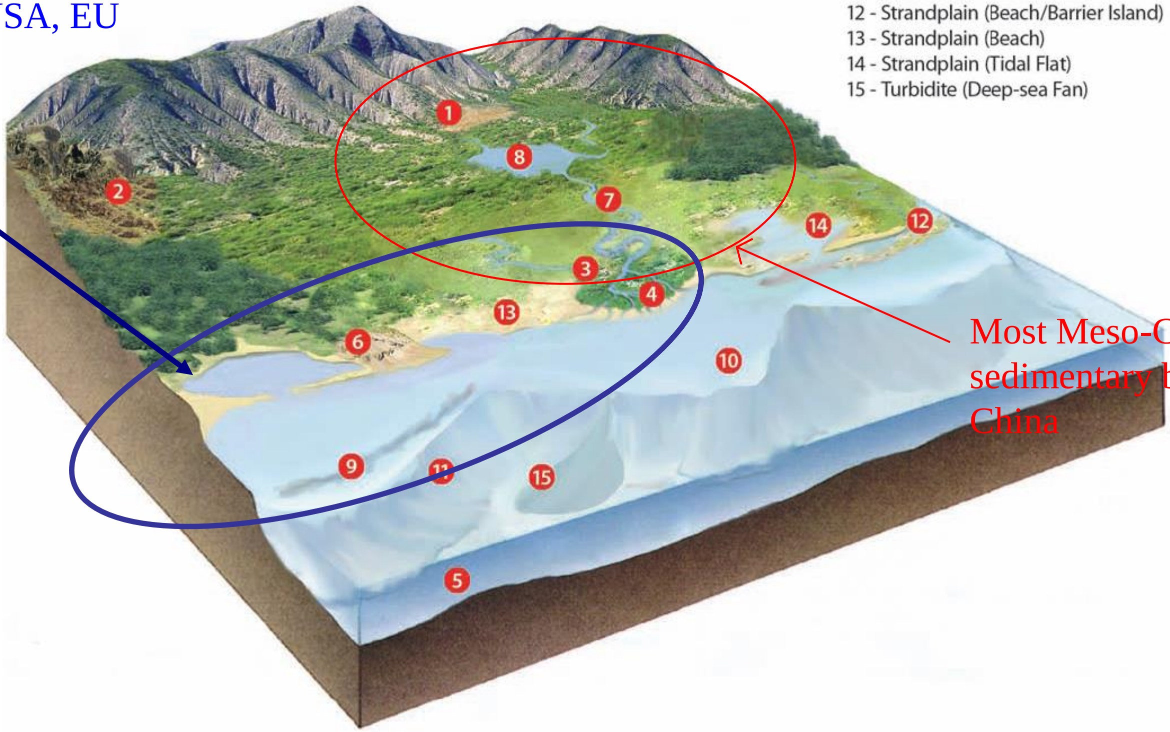
cags China Australia Geological Storage of CO_2

中澳二氧化碳地质封存

Major geological setting of Chinese Basin

The basic features of sedimentary basins in China

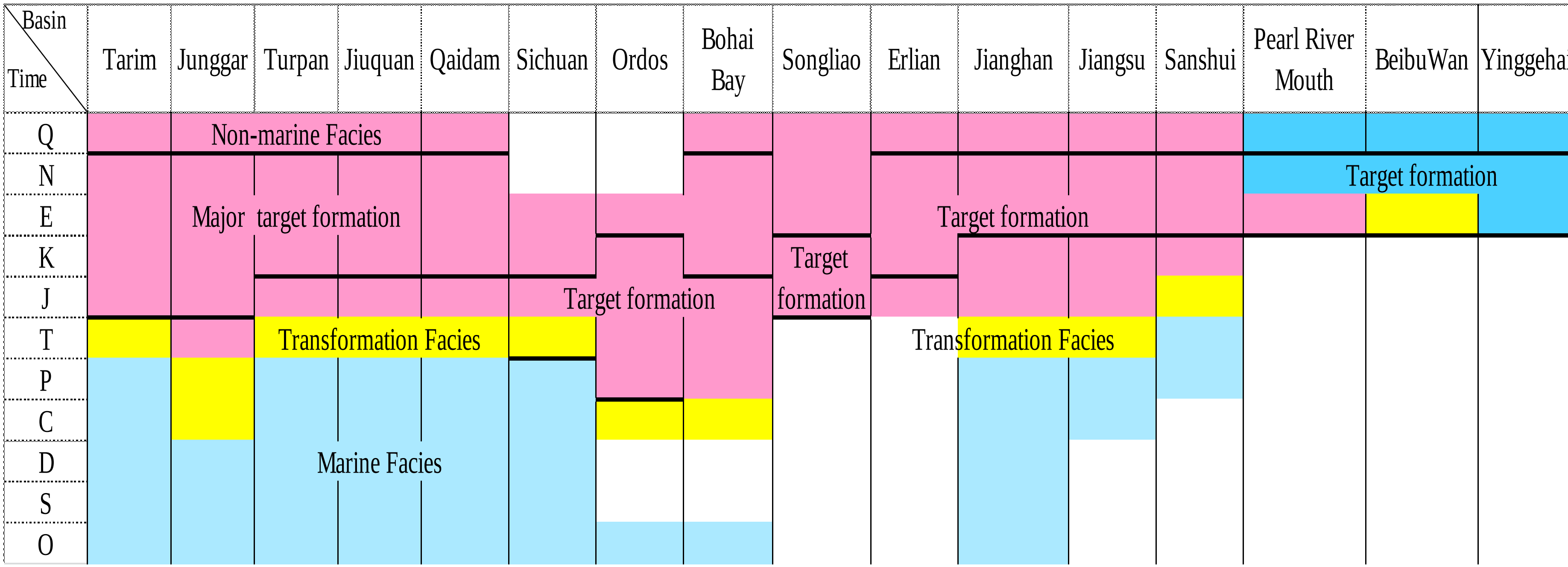
Most sedimentary basins in USA, EU and other countries



Most Meso-Cenozoic sedimentary basins in China

NETL, 2010

Major geological setting of Chinese Basin

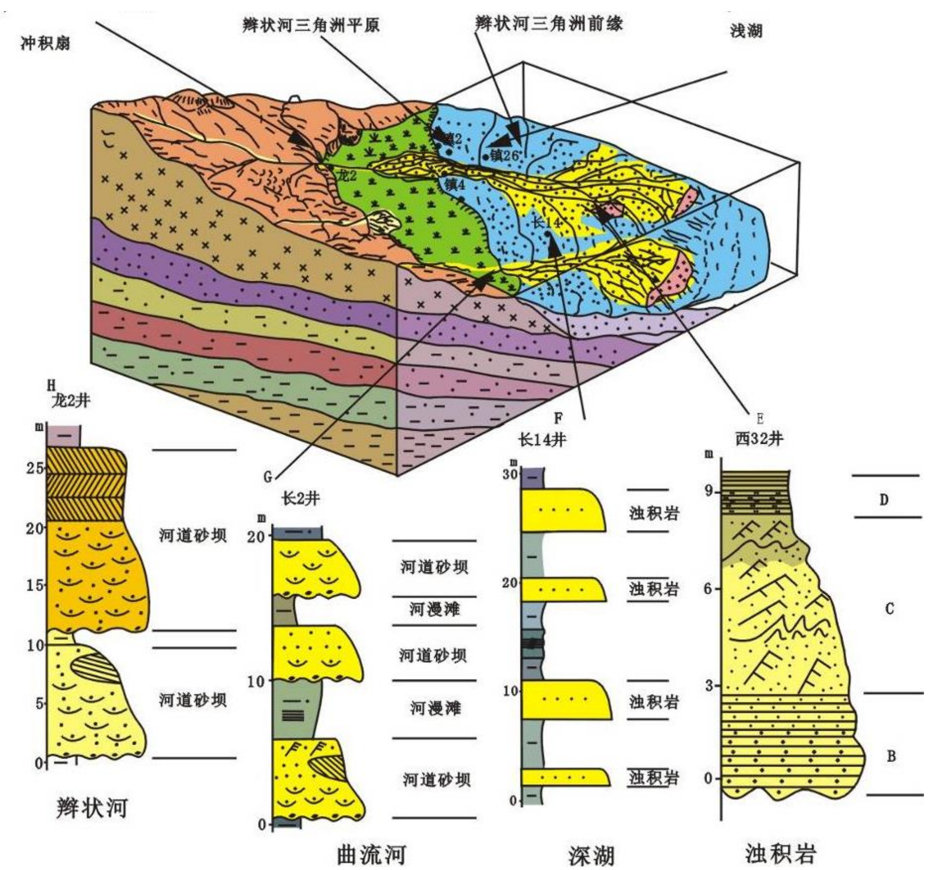


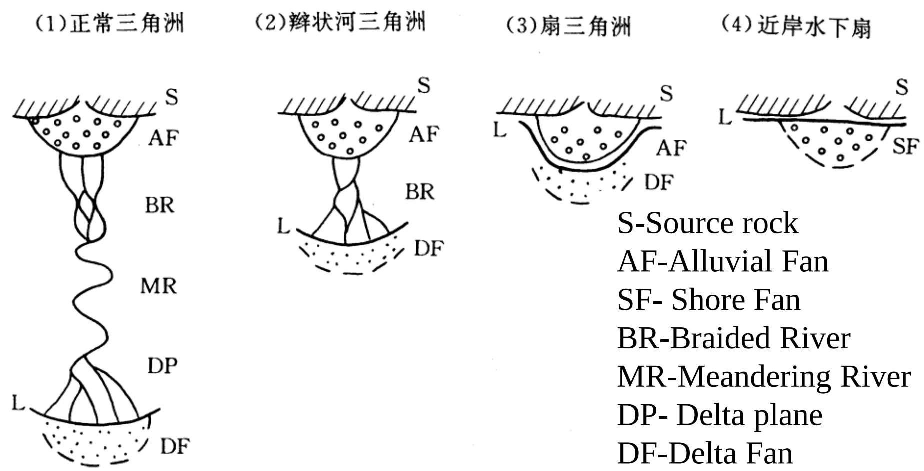
- Target storage formations are mainly formed by non-marine clastic deposits
- High heterogeneity and poor continuity of seal-reservoir pairs
- Challenges in prediction and assessment of sealing, injectivity and capacity

Non-marine models (Idar Akervoll, 2011)

Major geological setting of Chinese Basin

Sedimentary facies



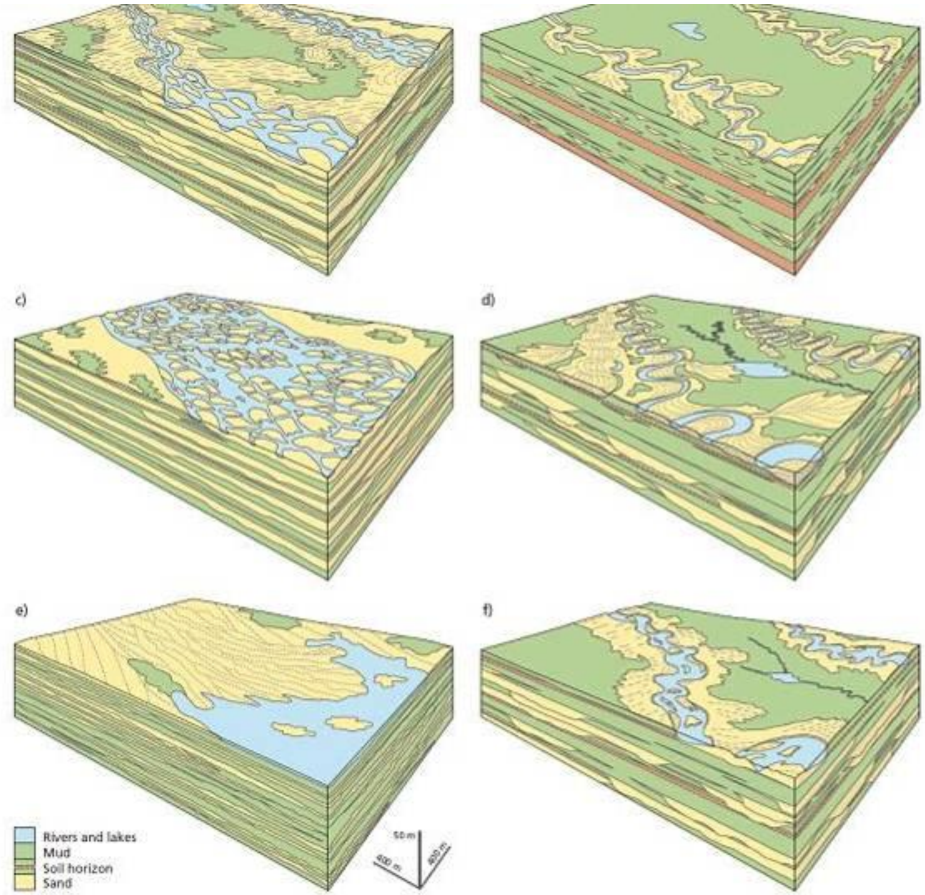


Sedimentary facies

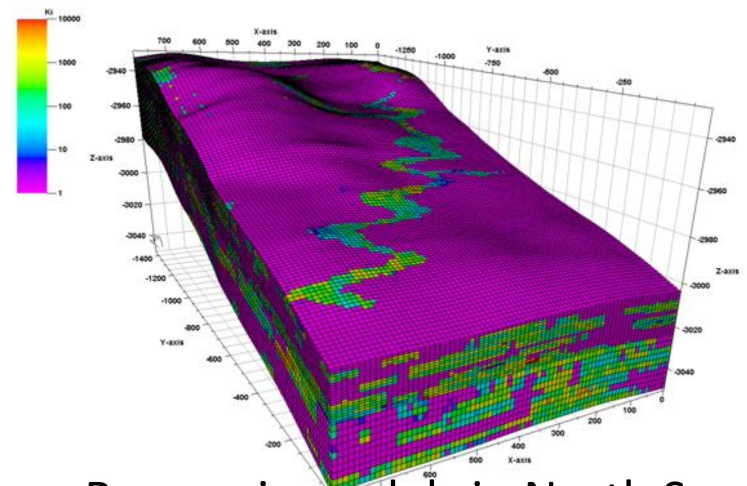
Knowledge of depositional environments and directional tendencies imposed by the deposition can influence how fluid flows within these systems today and how CO_2 would flow in the future.

Major geological setting of Chinese Basin

Sedimentary facies



Non-marine models (Idar Akervoll, 2011)



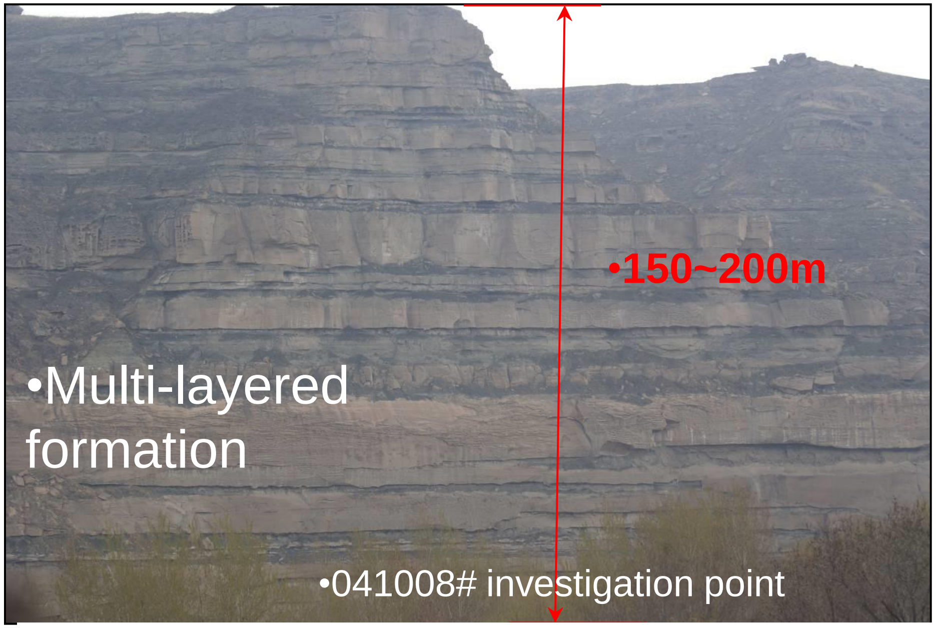
Reservoir models in North Sea
(Idar Akervoll, 2011)

2. Heterogeneity of seal-reservoir pairs –affecting the seal, capacity and injectivity.

“组合盖层”的非均质性质导致优势流动及其控制问题。直接关系到密封性、封存容量和注入性。

Major geological setting of Chinese Basin

Sedimentary facies



3. The low average thickness of seal-reservoir pairs (sedimentary rhythm)
平均层厚小

- **rhythm of sedimentary system**
- 多旋回沉积，平均层厚度数米, 盖层及盖层多而薄
- **Heterogeneity of seal-reservoir pairs**
- 应重视“组合盖层”的密封性评价，直接关系到密封性、封存容量和注入性。

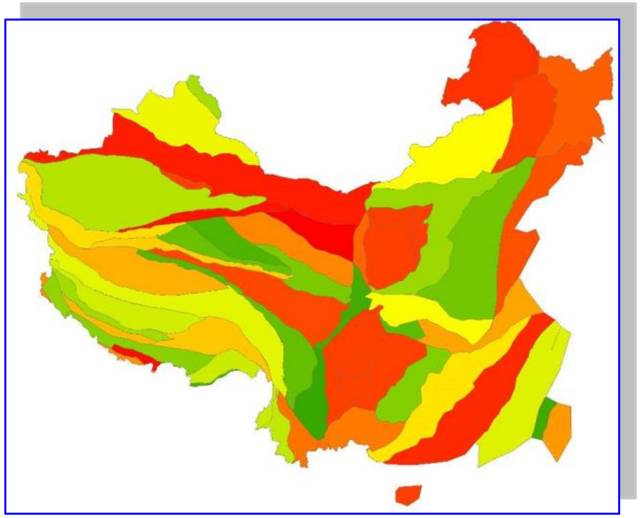
Outline

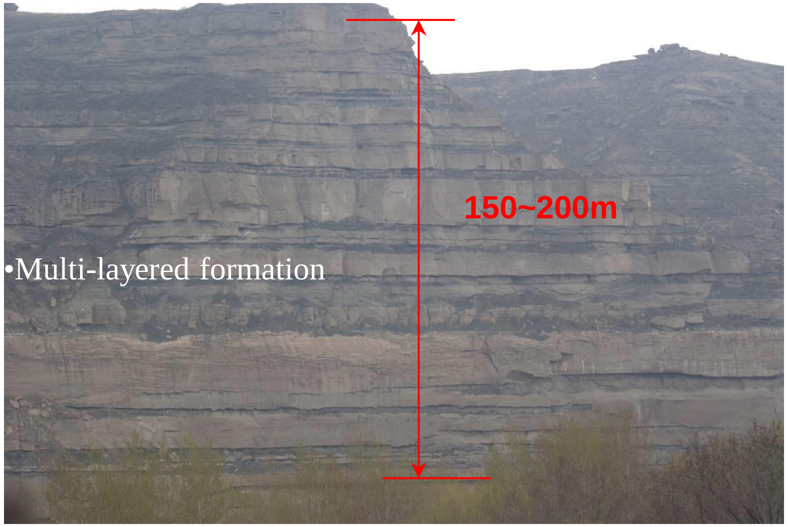
- ➢ Background of CO_2 geological storage
- ✓ CO_2地质封存背景
- ➢ Major geological setting of sedimentary basins in China
- ✓ 中国沉积盆地的主要地质特点
- ➢ **Major technical challenges related to geological setting**
- ✓ **地质特征导致的主要技术挑战**
- ➢ Possible solution to the technical challenges
- ✓ 可能的解决策略
- ➢ Summary
- ✓ 结论

Technical challenges for CO_2 geological storage in China

- **Main challenges related to geology feature**
- 地质特点导致的主要挑战
- **Technical challenges for CCS deployment in China**
- 中国的封存技术的主要技术障碍

Basin features and challenges: tectonic structure





•Small tectonic units and small basins are segmented by faults system

•Less stability of storage sites and tectonic units

•Challenges in the mechanical stability of faults and tectonic units
•Seal-reservoirs consist of multiple thin layers. The average thickness is from meters to twenty meters.
•Complex migration pattern of CO_2 plume and pressure plume in heterogeneous formation
•Challenges in monitoring and evaluation technologies.

Major geological challenges to CCS

Technologies challenges are mainly caused by tectonic activities and sedimentary history. Major challenges are as follows

- The stability of tectonic units and faults: Stability of tectonic unites might be affected by large-scale injection, cause stability problems, such as induced seismic activities, faults re-activity. The Seal ability and stability of caprock should be evaluated carefully before large-scale injection.
- The stability of caprock: High pressure injection might fracture the caprock with the complex in-situ stress field and complex structure.
- Safety of operation and after closure: the facility need for further improvement for complex geological feature
- Migration of CO_2 and pressure plume: Multi-layered and heterogeneous seal-reservoirs pairs decreases the sweep efficiencies , effective storage capacity and cause preferential migration, special injection strategy is needed. Special attention should be paid for those formations with braided and meandering facies.
- Risk mitigation method. Leakage prediction and mitigation methods are very important for preferential migration and possible leakage scenario.

Technical challenges for CO_2 geological storage in China

- **Main challenges related to geology feature**
- 地质特点导致的主要挑战
- **Technical challenges for CCS deployment in China**
- 中国的封存技术的主要技术障碍

Technical challenges for CO_2 geological storage in China

The phases of CO_2 geological storage projects

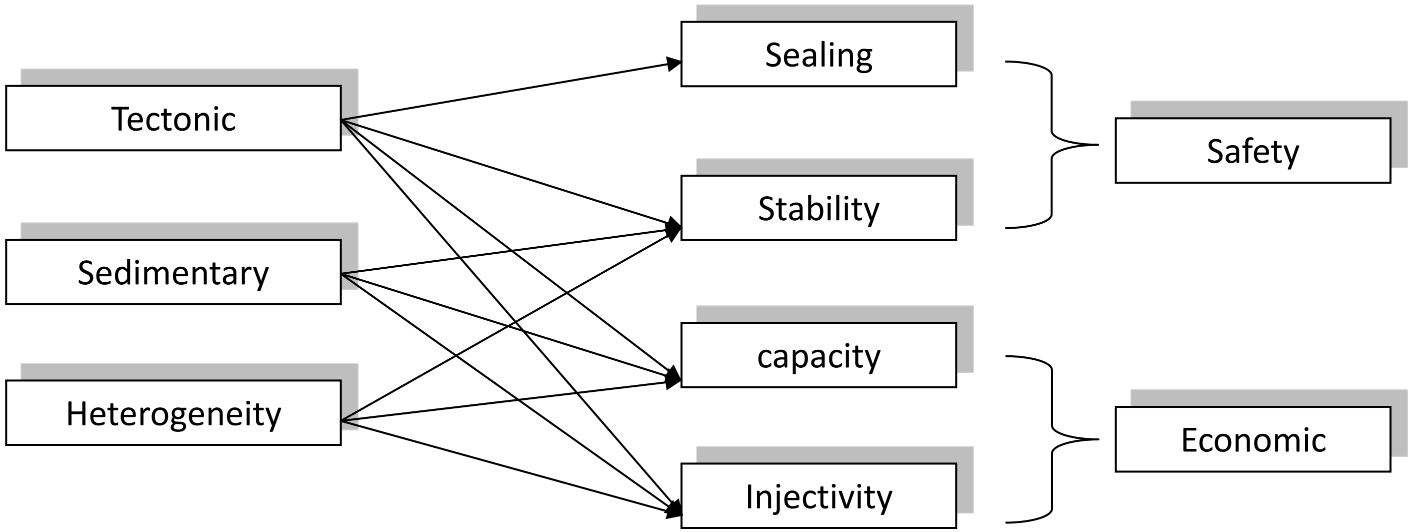
Identify candidate sites → Characterize and evaluate site → Prepare site → Operate site → Close site → Post closure site care

★Screening/Characterization （2~5years）	★Operation phase(20~50y)	★Phase-Closure/Post-Closure(500~1000y）
-Site Screening -Exploration Permit -Site Characterization -Site Selection -Project plan and primary design	-Storage Permission -Site Design and Construction -Site Preparation -Injection/Post-injection -Monitoring & Evaluation -Environmental Evaluation	- Site Closure Permit -Decommissioning -Site Closure Certificate -Transfer of Liability -Long-term monitoring and managing

Development phases associated with CO_2 storage projects

The different stages will face different technical challenges

The possible solution to those technologies barriers



- Site characterization and evaluation technologies with high definition： 高精度的物探、测井、试井等测试数据用于密封性、封存量、可注性、稳定性等场地评估;
- High definition model and prediction technologies： 储盖层的精细建模、取值及预测技术
- Monitoring and verification technologies： 监测技术的准确性与封存过程评价技术
- Process and risk management： 压力与晕控制、控流、堵漏等过程控制与风险管理技术

The geological feature bring lots challenges to CCS deployment in China
中国特殊地质要求更高精度和针对性的技术与设备;

Outline

- ➢ Background of CO_2 geological storage
- ✓ CO_2地质封存背景
- ➢ Major geological setting of sedimentary basins in China
- ✓ 中国沉积盆地的主要地质特点
- ➢ Major technical challenges related to geological setting
- ✓ 地质特征导致的主要技术挑战
- ➢ **The possible solution to technical challenges**
- ✓ **可能的解决策略**
- ➢ Summary
- ✓ 结论

The possible solution to technical challenges

- Carry out technology R &D activities toward geological feature in a more strategic way, including, large-scale well drilling, storage technologies, site characterization and prediction, site screening and selection, process optimization, risk management, monitoring and safety evaluation technologies , and so on.
- 针对地质特点战略性地开展CCS关键技术的研发与示范，包含：规模化钻井、封存技术、场地表针与筛选、过程优化、风险控制、安全监测与评价等技术。

The possible solution to technical challenges

R & D activities of CCS technologies

技术群 technologies	要素技术 technology components
场地表征与适宜性评价 Site characterization, and evaluation	场地勘察与现场测试 high definition characterization technologies
	室内测试与参数取值 Lab experiment and properties up-scaling technologies
	复杂地质体系的建模与模拟技术 modeling with high definition geological data
	复杂地质条件的评价方法 evaluation method on complex geological formation- such as, faults, caprock integration, migration pathways and so on
施工与运行管理 Development and operation management and optimization	钻井、固井与完井 Well drilling & complication with multi-layered formation
	选层技术 Formation selection
	地面设施 Surface facilities
	井下施工设备 Underground facilities
	工程试运行与重评估 Testing and re-evaluation of projects
监测与预警 Monitoring, evaluation, and pre-warning tech	物理方法 Geophysics monitoring methods, such as, 3D 2D seismic investigation
	地球化学监测 Geochemistry
	深井实时多物理量监测 down-hole monitoring-P/T/Q/
	深井实时多层取样 real-time multi-layered formation sampling
	微震监测与评价 micro-seismic monitoring and evaluation
	地面变形 surface deformation
	地面大气、土壤环境监测 gas monitoring
	其他技术 other monitoring technologies
风险管理 Risk management	修井技术，套管、水泥等补救技术 workover ,such as, casing, cement, workover
	封隔器失效 well packer failure
	井喷制止 CO_2 eruption
	地层泄漏 leakage
	诱发地震调控 mitigation of induced seismic events

Outline

- ➢ **Background of CO_2 geological storage**
- ✓ CO_2地质封存背景
- ➢ **Major geological setting of sedimentary basins in China**
- ✓ 中国沉积盆地的主要地质特点
- ➢ **Major technical challenges related to geological setting**
- ✓ 地质特征导致的主要技术挑战
- ➢ **The possible solution to the technical challenges**
- ✓ 可能的解决策略
- ➢ **Summary**
- ✓ 结论

Summary

- There are huge CCS potential for CCS deployment in China
- 中国具有巨大地CCS实施潜力。
- The unique tectonic structure and sedimentary history of bring challenges and uncertainty to CO_2 aquifer storage technologies
- 中国的CO_2封存场地的构造和沉积环境带来了特殊的地质特征，同时也给CO_2咸水层封存带来了一系列的技术挑战和不确定性。
- The solution to those challenges are R &D of key technologies in a strategic way.
- 建议的应对挑战的措施：策略性的关键技术的研发与示范。

Thank you！

for your attention!

Email: Nwei@whrsm.ac.cn