中国地质调查局
水文地质环境地质调查中心
Center for Hydrogeology and
Environmental Geology Survey,CGS

Study on suitability site selection of CO_2 storage project

二氧化碳地质封存场地选址研究

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概　述

二氧化碳地质储存从国家区域性的评价到具体工程的实施是一个系统的过程。考虑到中国沉积盆地的复杂性、活动断裂与地震等地质安全性、二氧化碳地质储存地质条件的特殊性与苛刻性等因素，需建立起一套符合中国特点的完整的调查评价方法体系，以指导中国二氧化碳地质储存实践。

借鉴碳封存领导人论坛（CSLF）和国内外相关研究成果的基础上，特别是中国地下水、油气资源、固体矿产等循序渐进、分阶段勘查开发的基本原则，中国地质调查局水文地质环境地质调查中心将中国二氧化碳地质储存潜力与适宜性评价工作划分为五大阶段。第一阶段为区域级预测潜力评价阶段，第二阶段为盆地级推定潜力评价阶段，第三阶段为目标区级控制潜力评价阶段，第四阶段为场地级基础储存量评价阶段，第五阶段为灌注级工程储存量评价阶段。

对应二氧化碳地质储存选址研究而言，第一、二、三阶段为规划选址阶段。第四阶段即工程选址阶段，开始于沉积盆地各三级构造单元二氧化碳地质储存目标靶区评价所筛选出的比选场地。通过对各比选场地相关资料全面搜集、遥感选址调查、现场实地综合地质调查、地球物理勘探等工作，获取各类评价参数，详细评价这些比选场地，选择出优选场地，最终评价推荐出当地公众、政府和业主可接受的工程场地。

在整个场地选址过程中，目标靶区的选取与评价将是一个非常重要的阶段，具有承上启下的作用。一方面，“目标靶区”是盆地级潜力与适宜性评价得出的，有进一步开展选址研究价值的地区；另一方面，“目标靶区”是二氧化碳地质储存工程选址的起点和主要依据。目标靶区的选取与评价首先要建立一套完善的评价方法体系。本着“安全性第一，既经济又技术和环境友好”等原则，通过地质安全性、储存规模、社会环境风险和经济适宜性4个指标层，44个指标来进行评价。

本次将通过中国已开展和正在开展几项二氧化碳地质储存选址案例，介绍场地选址的一般过程。

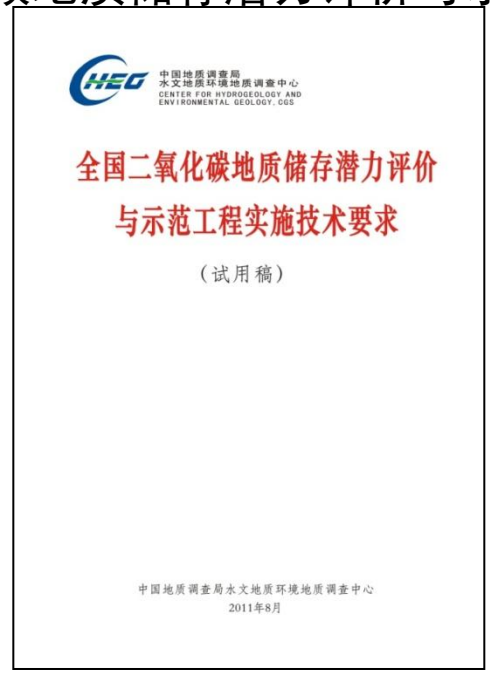
OUTLINE

- Methodology on CO_2 Geological Storage in China
- 中国二氧化碳地质储存适宜性评价方法体系
- Technical Method of Sites Selection of CO_2 storage project
- 二氧化碳地质储存场地选址调查与评价方法
- Cases
- 案例分析
- Conclusions
- 结论

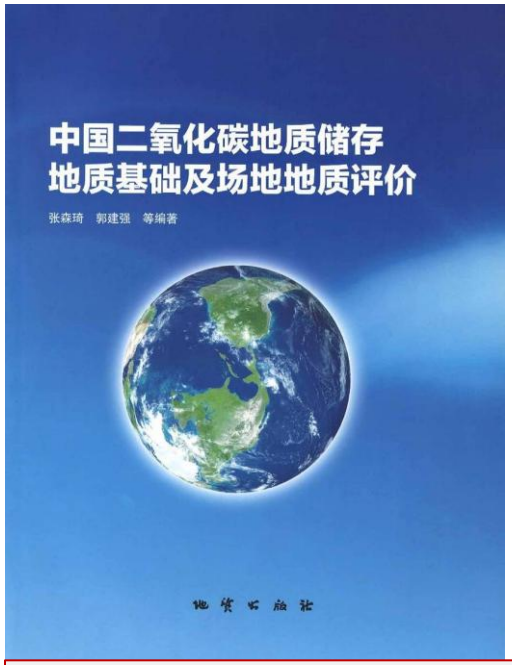
Methodology on CO_2 Geological Storage in China

Study on basic geological conditions on CO_2 Geological Storage in China, and draw up the Technical Requirements on Capacity Evaluation and Pilot-projects Development of CO_2 Geological Storage，Guideline Study on Site Selection in China.

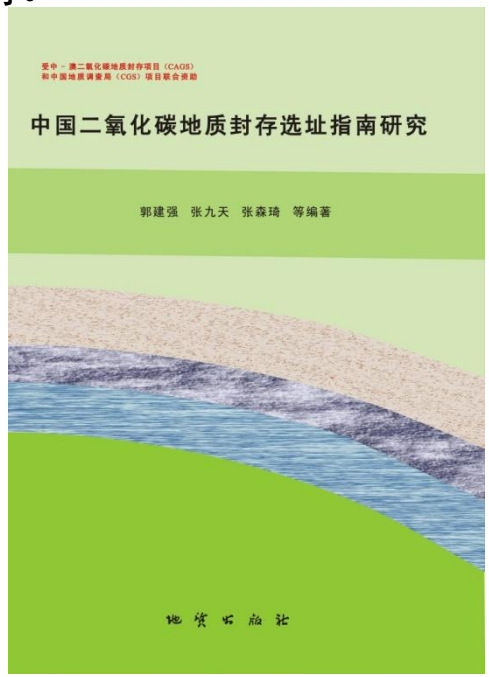
借鉴国外经验，研究了中国二氧化碳地质储存基础地质条件，编制了中国二氧化碳地质储存潜力评价与示范工程技术要求、选址研究指南。



Technical Requirements on Capacity Evaluation and Pilot-projects Development of CO_2 Geological Storage



Basic Geological Conditions and Evaluation on CO2 Geological Storage in China



Guideline Study on Site Selection of CO2 Geological Storage in China

Based on the potential evaluation scales dividied by Carbon Sequestration Leadership Forum (CSLF) and hydrogeological exploration experiences, we divided the potential evaluation scales into the following 5 stages.

借鉴碳封存领导人论坛和地下水、矿产勘查经验，将我国二氧化碳地质储存潜力评价分为五个阶段。

Evaluation stages

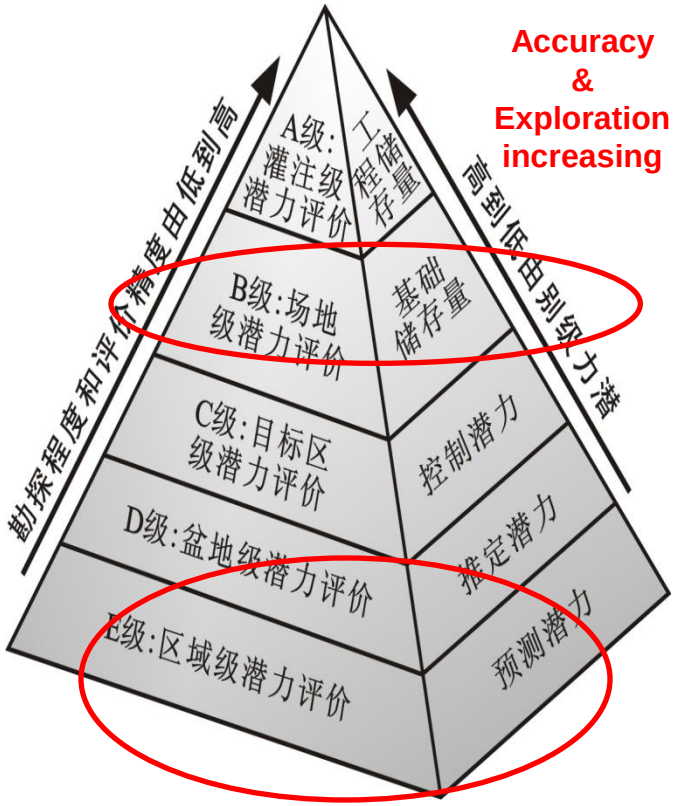
A级：灌注级潜力评价
Injection scale

B级：场地级潜力评价
Site scale

C级：目标区级潜力评价
Target scale

D级：盆地级潜力评价
Basin scale

E级：区域级潜力评价
Regional scale



Potential levels

工程储存量
Project capacity

基础储存量
Basic capacity

控制潜力
Controlled potential

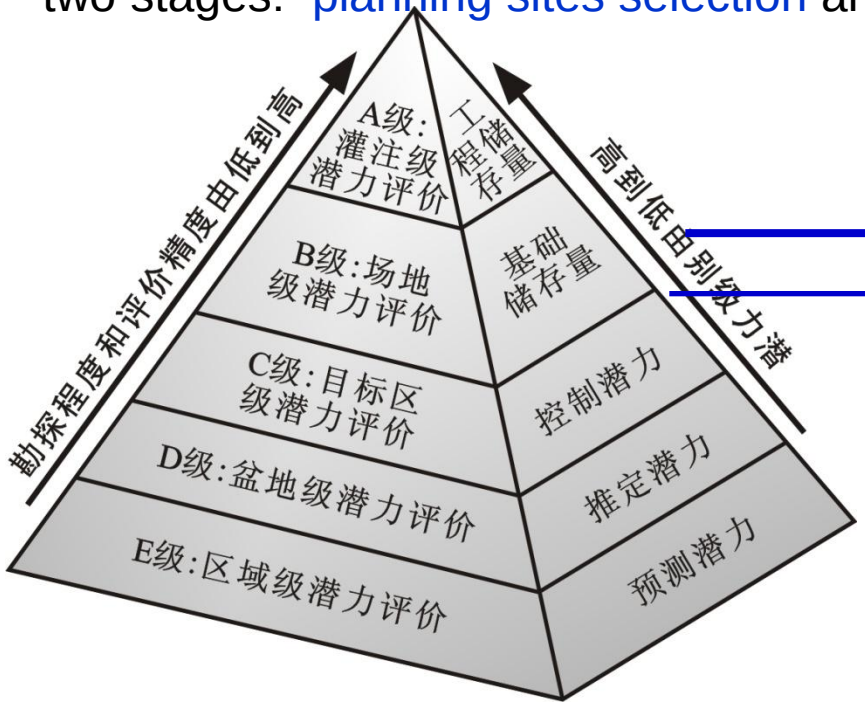
推定潜力
Inferred potential

预测潜力
Predicted potential

选址阶段　Sites selection stage

借鉴国外选址经验，结合中国二氧化碳地质储存潜力与适宜性评价工作基础，将中国深部咸水层二氧化碳地质储存选址评价分为两大阶段：规划封存选址和封存场地选址。

Refer to the sites selection experience abroad and combined the CO_2 storage capacity and suitability estimation, the sites selection estimation is divided into two stages: planning sites selection and project sites selection.



封存场地选址
project sites selection

规划封存选址
planning sites selection

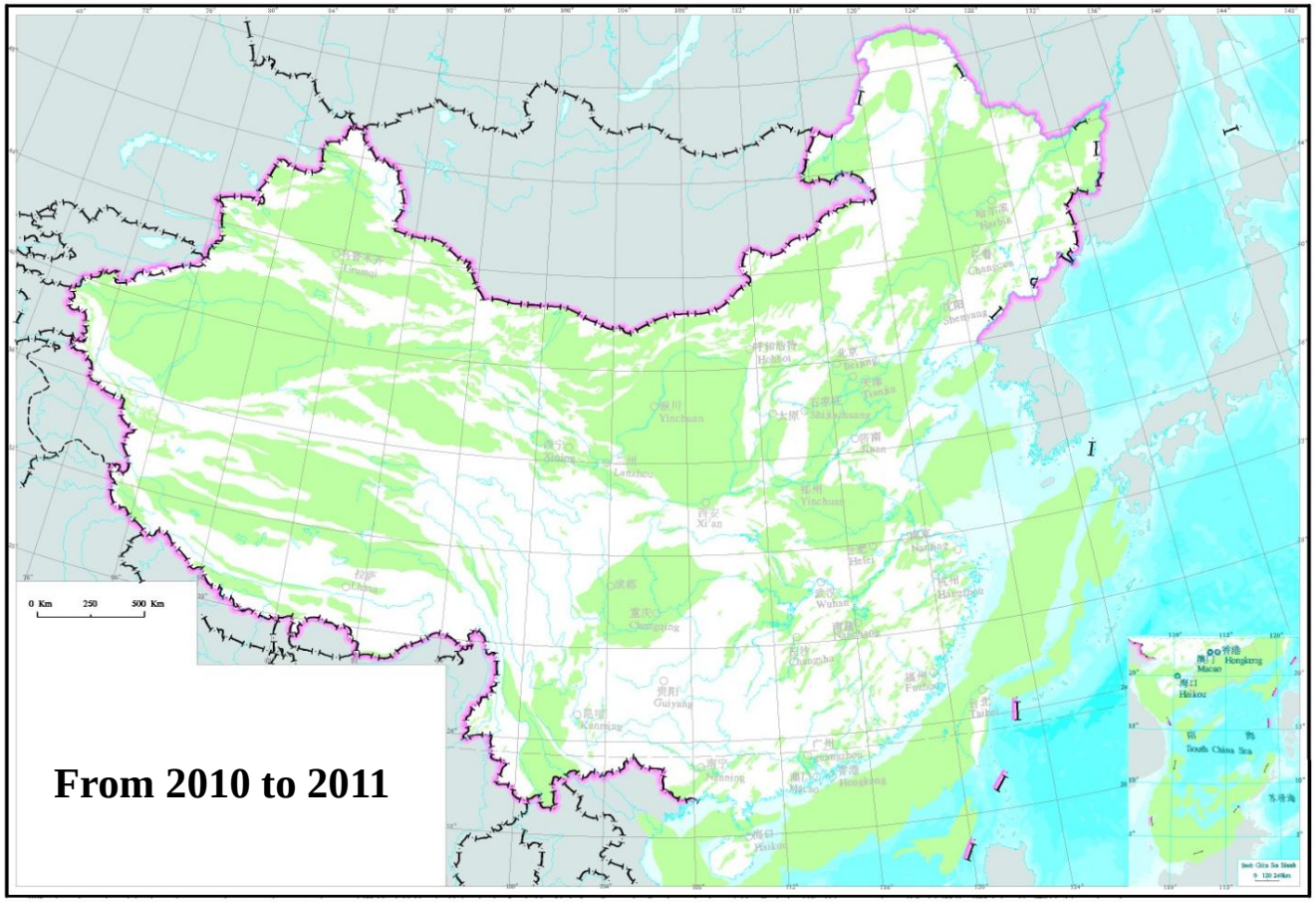
1. Evaluate Regional Scale Potential and Draw Maps
区域级二氧化碳地质储存潜力与适宜性评价及编图

Storage Types

- deep saline aquifers
- oil reservoirs
- gas reservoirs
- coal beds

储存介质类型

- 深部咸水层
- 油藏储层
- 天然气藏储层
- 煤层



Areas & quantity 评价范围和数量

Assessment unit : every sedimentary basin in China 评价单元：中国的每一个沉积盆地

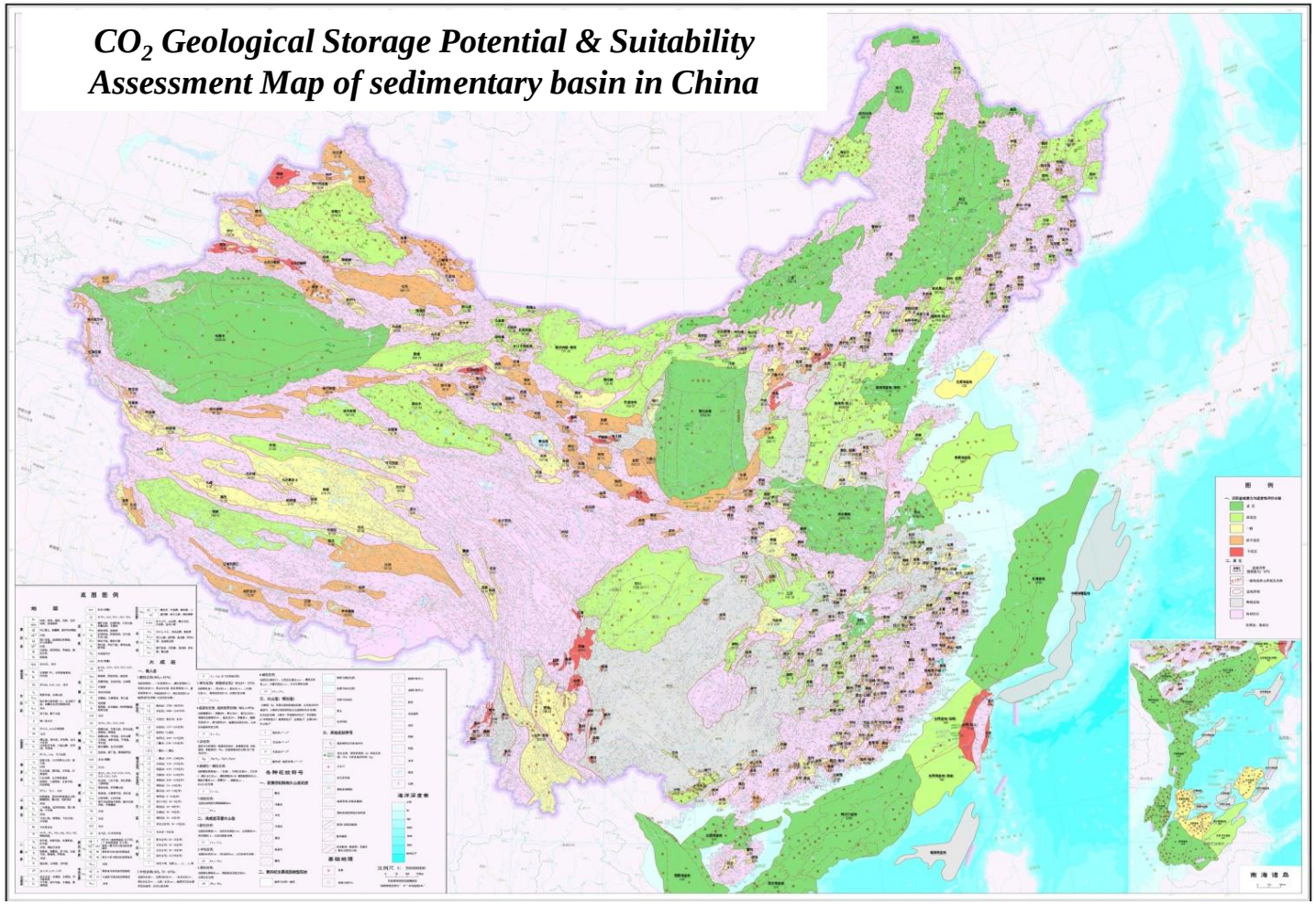
Sedimentary Basins Quantity: 417 (>200km^2) 沉积盆地数量：大于200km^{2}的盆地417个

Total areas: 5.86Million km^2 总面积：586万km2

Evaluation Criteria on Regional Scale 区域级评价指标

指标评价层 Index layers	评价指标亚层 Evaluation Index sublayers	适宜 highly suitable	较适宜 suitable	一般 Possible	较不适宜 Unlikely	不适宜 Unsuitable
基础地质条件 Basic Geological Condition of Basin	面积Area (km^2)	＞50000	25000～50000	5000～25000	200～5000	＜200
	沉积深度Sedimentary Depth(m)	＞3500	3500～800	800～600	600～300	＜300
	盆地性质Basin character	压性 Pressed	压扭性 Pressed-Twisted	扭性 Twisted	张扭性 Tension-Twisted	张性 Tension
研究程度和资源潜力评价 Research Degree and Resources Potential	勘探程度 Exploration Degree	开发中 Development	勘探程度高 High	勘探程度一般 General	勘探程度低 Low	未勘探 No
	数据支持情况 Exiting data	数据充分，可靠 Full, reliable data	数据较充分，较可靠 Less full data	数据一般充分，一般可靠 General full data	数据不太充分 Not sufficient date	数据不充分 No date
	资源潜力 Resources potential	大 Large	较大 Relatively large	一般 General	较小 Relatively less	小 Less
地壳稳定性评价 Crustal Stability	区域地壳稳定性Regional Crustal Stability	稳定 Stable	基本稳定 Basically stable	略不稳定 Slightly unstable	次稳定 Less stable	不稳定 Unstable
地热地质条件评价 Geothermal Geology	地表温度 Land Surface Temperature(℃)	＜－2	－2～3	3～4	10～25	＞25
	地热流值Geothermal heat flow value（mW/m^2）	＜54.5	54.5～65	65～75	75～85	＞85
	地温梯度Geothermal gradient(℃/100m)	＜2.0	2.0～3.0	3.0～4.0	4.0～5.0	＞5
社会经济条件评价 Social&Economic Condition	人口密度 Population density(Person/km^2)	0～50	50～100	100～200	200～1000	＞1000
	土地利用条件 Land use types	沙漠 Desert	草地 Grassland	林地 Woodland	耕地 Arable land	居民区 Settlements
预测潜力评价 Predicted potential	预测潜力 Predicted potential(10^8t)	>1000	100~1000	5~100	0.5~5	<0.5
	单位面积预测潜力Predicted potential per area (10^4t/km^2)	>500	100~500	50~100	5~50	<5

Potential & Suitability Assessment of the Sedimentery Basins in China
中国沉积盆地二氧化碳地质储存潜力与适宜性评价图



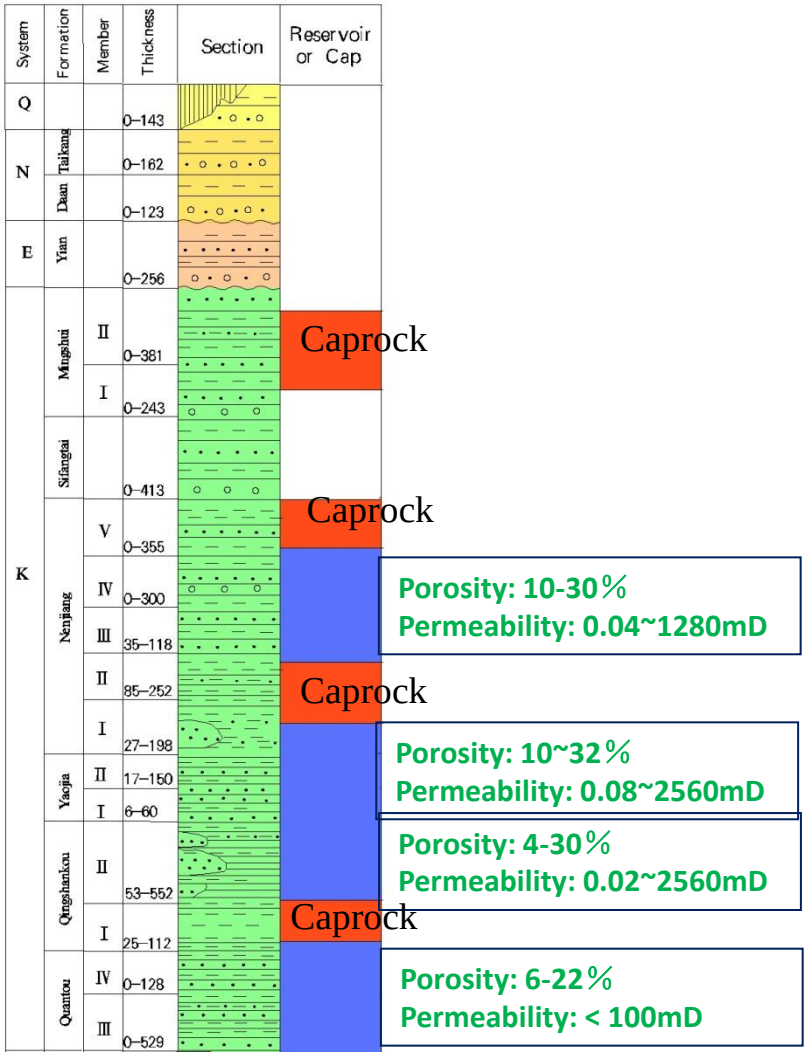
2. Evaluate Regional Scale Potential and Draw Maps
盆地级二氧化碳地质储存潜力与适宜性评价及编图

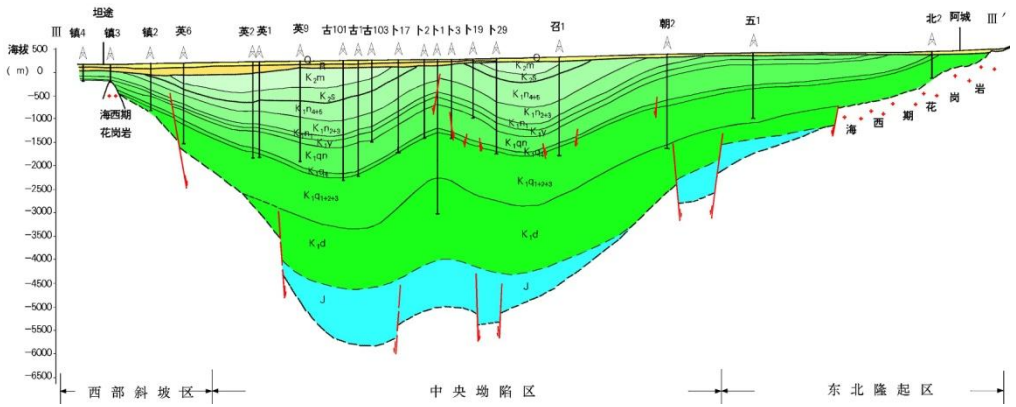
评价指标体系 Evaluation Criteria

指标评价层 Index layers	评价指标亚层 Evaluation Index sublayers
一级构造单元基础地质 Basic Geological Condition in First-order Tectonic	面积Area
	沉积深度Sedimentary Depth
研究程度和资源潜力 Research Degree and Resources Potential	勘探程度 Exploration Degree
	数据支持情况 Exiting data
	资源潜力 Resources potential
地壳稳定性Crustal Stability	区域地壳稳定性 Regional Crustal Stability
地热地质 Geothermal Geology	地表温度Land Surface Temperature
	地热流值Geothermal heat flow value
	地温梯度Geothermal gradient
社会经济 Social&Economic Condition	人口密度 Population density
	土地利用条件 Land use types
一级构造单元推定潜力 Inferred Potential in First-Order Tectonic	推定潜力Inferred potential
	单位面积推定潜力Inferred potential per area
一级构造单元储盖层条件 Reservoir and Cap Condition in First-order Tectonic	储层条件Reservoir condition
	盖层条件Cap condition
	储盖组合Combination of reservoirs and caps

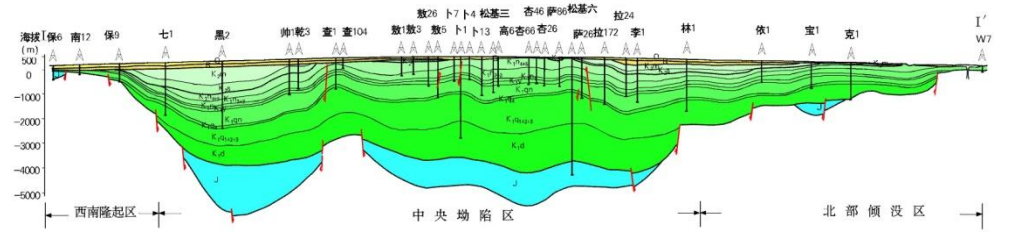
Case： Atlas of CO_2 Geological Storage in Songliao Basin

地质条件 Geologically





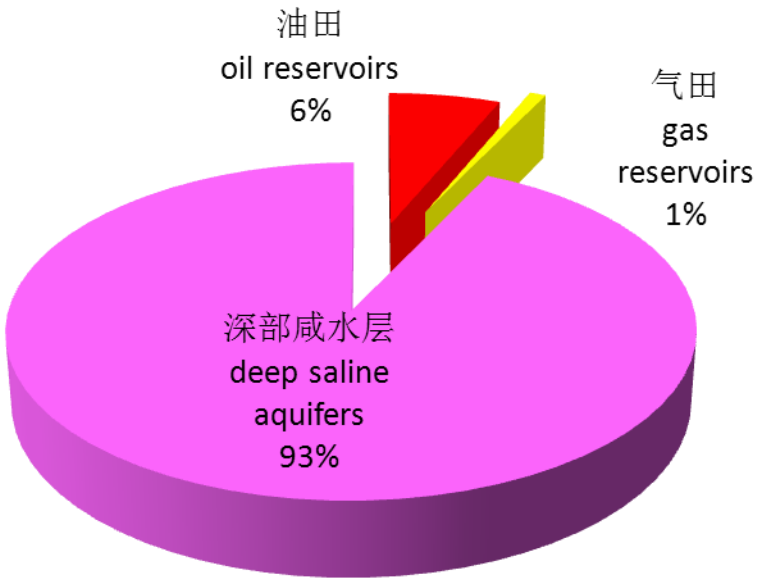
东西向剖面From West to East

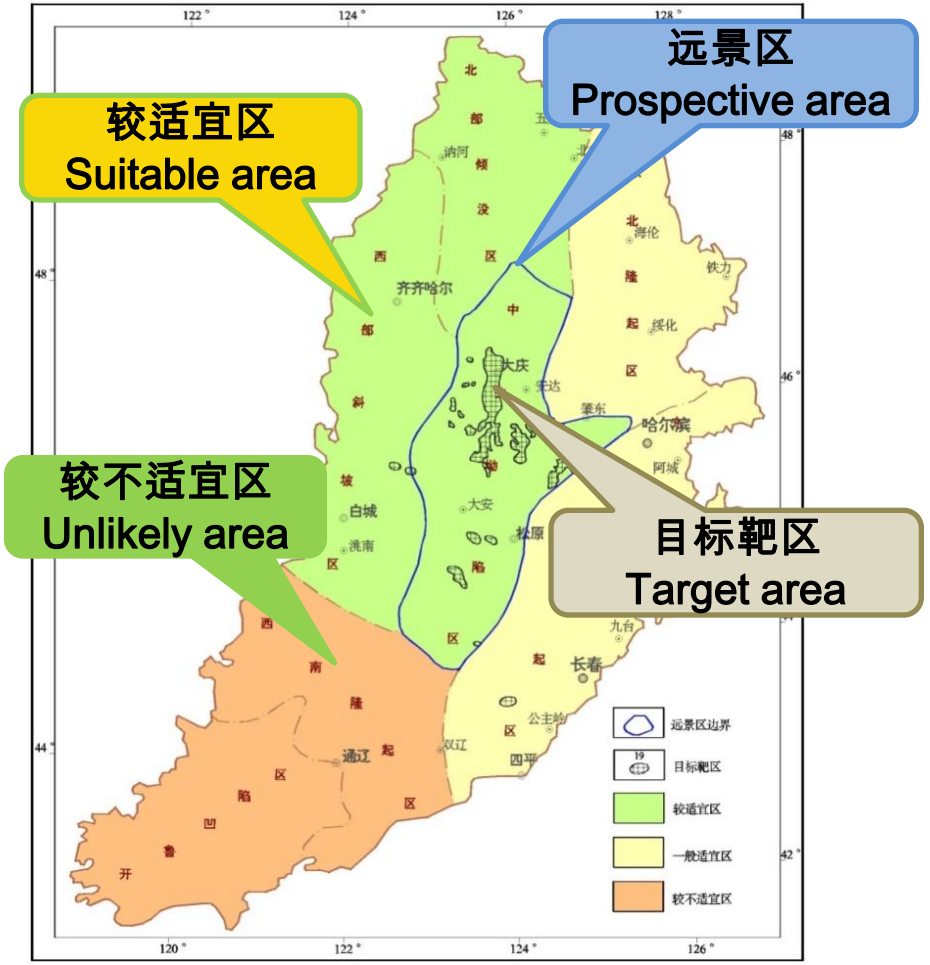


南北向剖面From North to South

The evaluation results of Songliao Basin

The inferred capacity

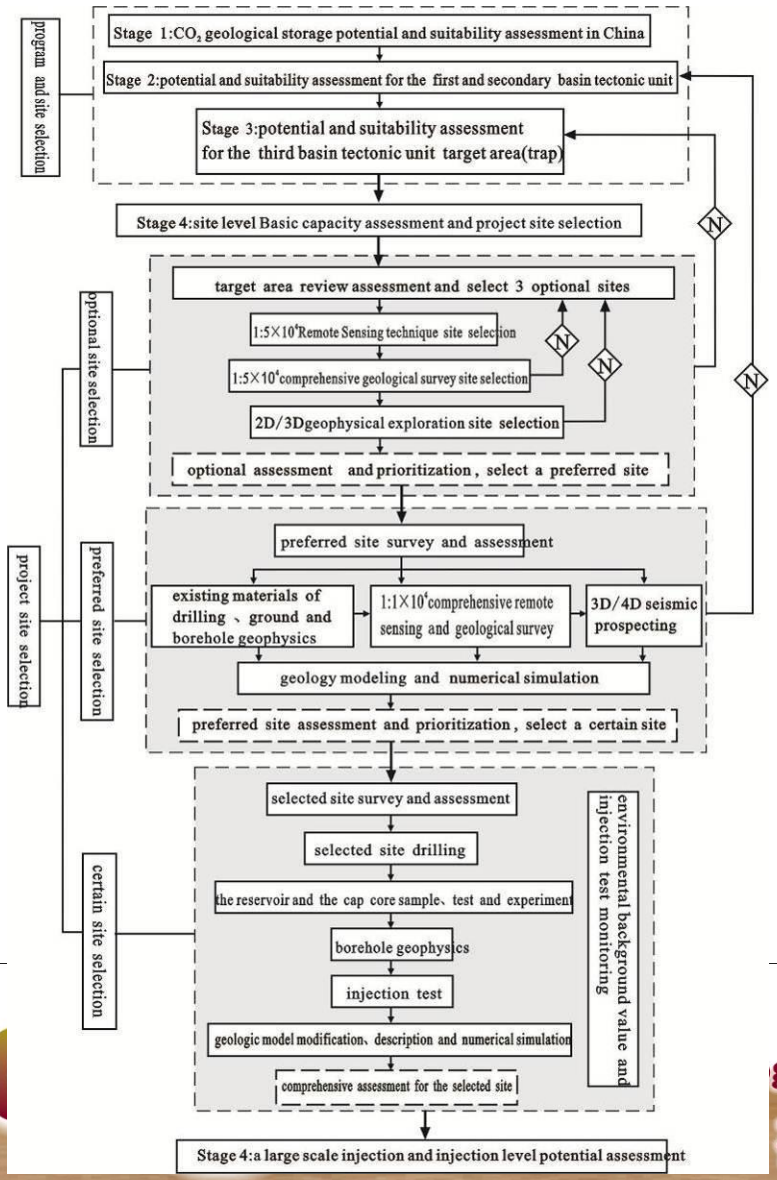




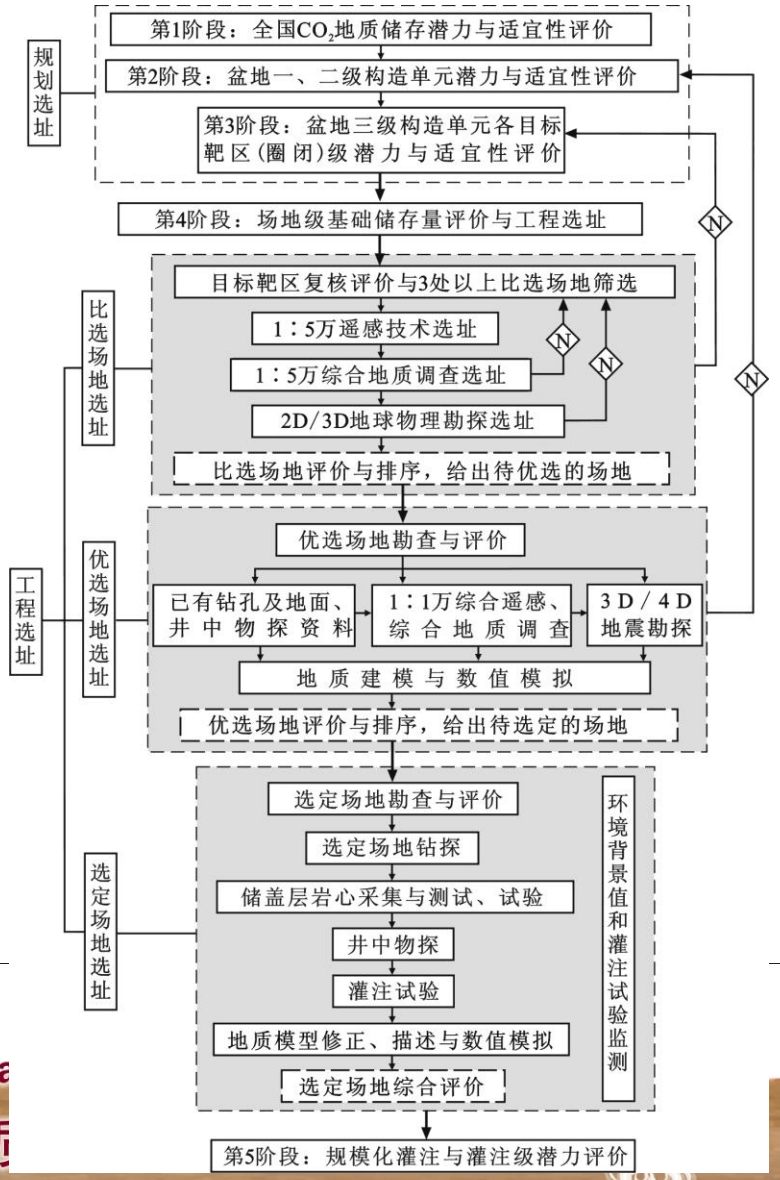
Suitability Evaluation Map

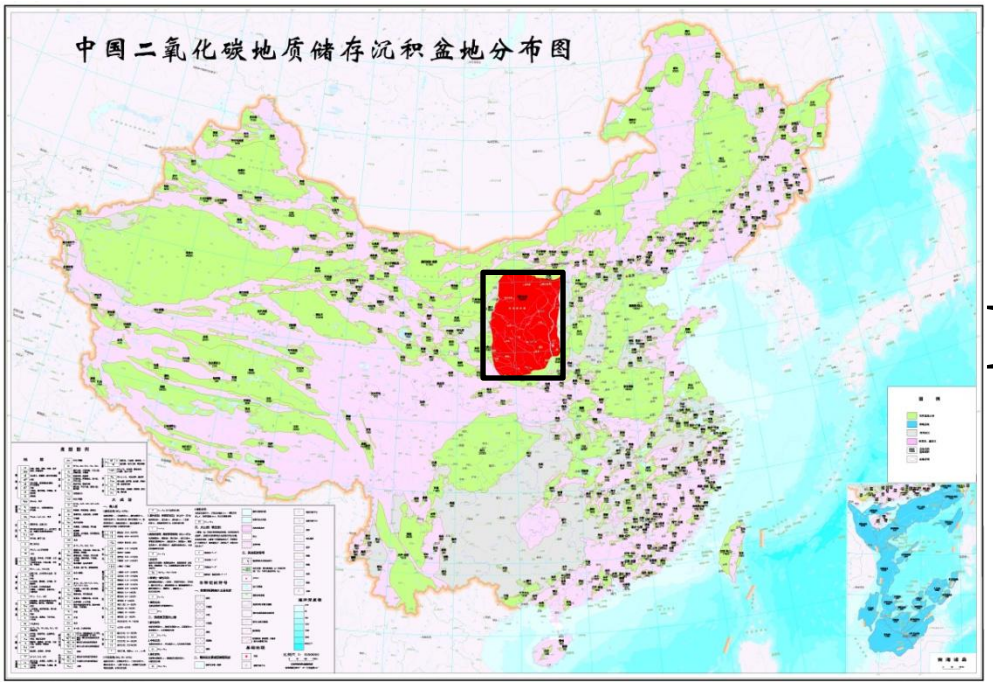
Technical Method of Sites Selection of CO_2 storage project

Flowchart of Site Selection of CO_2 Geological Storage

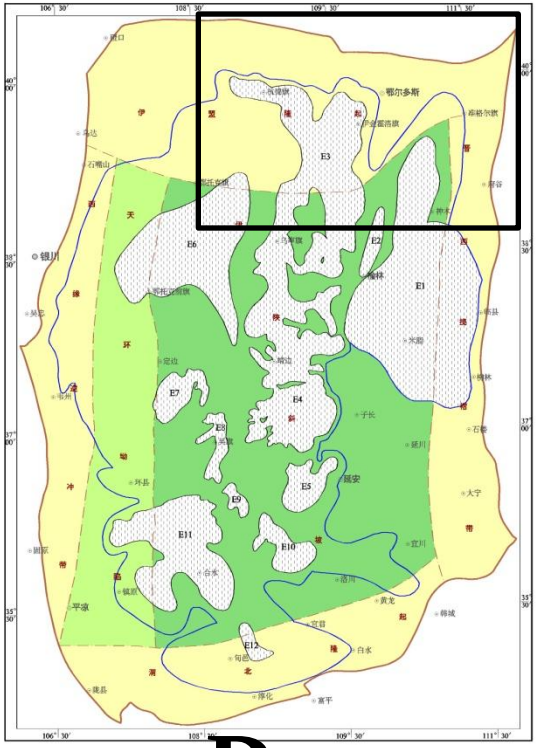


二氧化碳地质储存选址工作流程图

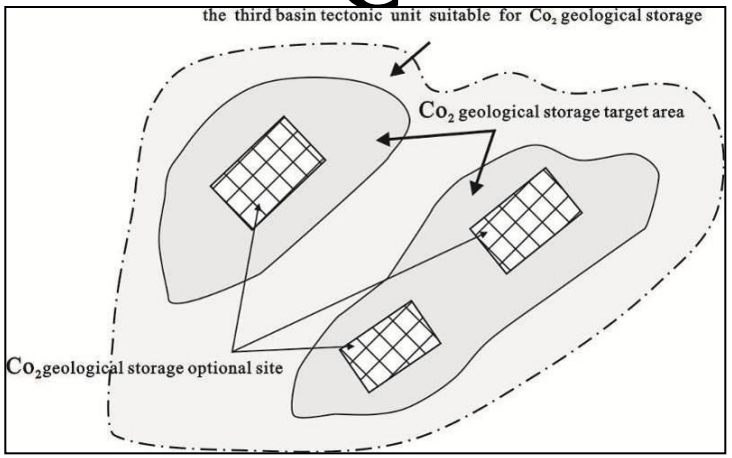



中国二氧化碳地质储存沉积盆地分布图

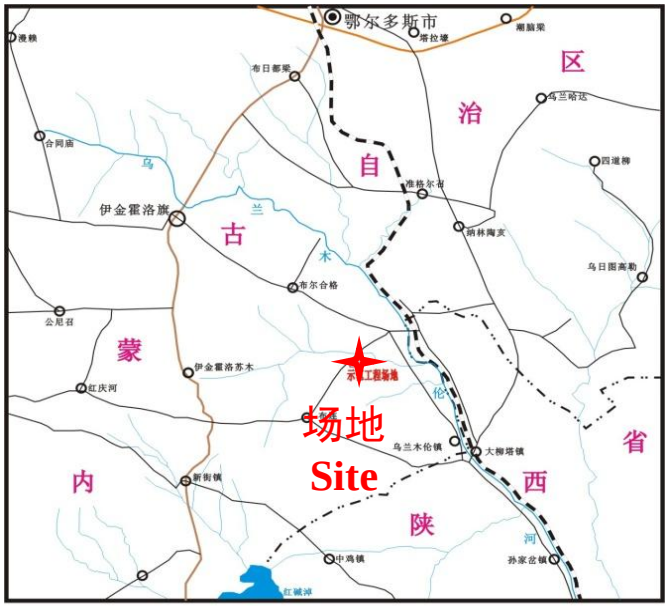
E → D


鄂尔多斯
E3
E6
E2
E1
E7
E4
E8
E5
E9
E11
E10
E12

D → C


the third basin tectonic unit suitable for Co2 geological storage
Co2 geological storage target area
Co2geological storage optional site

C → B


鄂尔多斯市
区
治
自
古
木
伦
河
蒙
内
陕
西
省
场地
Site

Criteria of Target Selection for CO_2 geological storage in deep salt groundwater

Layer	Sub-layer	Indicators
Safety	1.Crustal stability	①Motion peak acceleration of earthquake;②Earthquake;③Active faults within 25km
	2.Caprock	①Depth; ②Rock;③Single thick; ④Continuity; ⑤Permeability; ⑥Quality and quantity of sub-cover; ⑦ Microscopic closed index
	3.Faults and Leak	①Fracture development situation; ②If there are other drilling and abandoned wells deeper than 800 m in the target range; ③Unknown faults under the existing technical conditions
	5. Hydrogeology	①Hydrodynamics; ②Water head of deep saline aquifers
Reservoir	1. Reservoir feature	①Depth;②Thickness;③Sedimentary environment;④Stratigraphic combination and sand percent;⑤ Mineralization;⑥Formation pressure coefficient;⑦aspect ratio of effective reservoir
	2.Physical properties	①Porosity;②Permeability
	3.Geothermal	①Geothermal gradient;②Terrestrial heat flow;③Surface temperature
	4.Store prospect	①Effective storage;②service life
Socio-economic and environmental conditions	1.Reservoirs around	①Occasion to happen geological disasters;②Mining subsidence area, karst subsidence area;③Subsidence zone;④Desert activity;⑤Volcanic activity;⑥Lower than the highest water level of Rivers, lakes and reservoirs / flood storage;⑦Topography of perfusion site
	1. Social Environment	①population density;②The distance to city;③Land use
	2. Geological environment	①Geological disasters;②Whether in mining subsidence area, karst subsidence area, ground subsidence area, activity area desert, volcanic activity area;③Whether lower than highest water level of the rivers,lakes and reservoirs, or in floodplains
	3.Character of site	①City and regional development planning， Agricultural reserve, nature reserves, Scenic spot, cultural relics (archaeological) reserves, Life drinking water reserves, Water supply planning vision, mineral resources reserve districts and other zones that need special protection（Whether in special protection area）;②Vegetation status
	4.Safe distance to drink source	①Whether there is groundwater aquifers for industrial or agricultural use in the upper of CO_2 reservoir;② Whether in the main supply drinking groundwater area;③Distance to surface water source for drinking
Economical evaluation		①Carbon source;②Carbon source distance;③Mode of CO_2 transportation;④Mineral deposits

二氧化碳地质储存目标靶区评价主要指标构成简表

指标层	指标亚层	指 标 组 成
安全性	1、区域地壳稳定性	①地震动峰值加速度；②目标靶区地震安全性；③周边25km半径范围内是否有活动断层
	2、盖层宏观特征	①主力盖层的埋深；②盖层岩性；③主力盖层的单层厚度；④盖层分布的连续性；⑤渗透率；⑥主力盖层之上的二次截留能力；⑦盖层微观封闭性指数
	3、断裂泄露通道	①断裂和裂缝的发育情况；②目标靶区范围内是否有其他深度大于800 m的钻井及废弃井；③现有技术条件下未被发现的断裂
	4、水文地质条件	①水动力作用；②深部咸水层水头状态
储层规模	1、储层特征	①埋深；②厚度；③沉积环境；④地层组合与砂厚比；⑤矿化度；⑥地层压力系数；⑦有效储层长宽比
	2、储层物性参数	①孔隙度；②渗透率
	3、地热地质特征	①地温梯度；②大地热流值；③地表温度
	4、储层储存前景	①有效储存量；②使用年限；
社会环境风险	1、社会环境	①人口密度；②与城市的距离；③土地利用现状
	2、地质环境	①地质灾害易发性；②是否在采矿塌陷区、岩溶塌陷区、地面沉降区、沙漠活动区、火山活动区；③是否低于江河湖泊、水库最高水位线或洪泛区
	3、所在地区的性质	①是否符合城市和区域发展总体规划、是否在农业保护区、自然保护区、风景名胜区、文物保护区、生活饮用水源保护区与供水远景规划区、矿产资源储备区和其他需要特别保护的区域；②植被状况
	4、与饮用水源的关系和距离	①CO_2储层上部是否有可供工农业利用的地下水含水层；②是否在饮用地下水主要补给区内；③距离河流、水库等地表饮用水水源的距离
经济适宜性	1、内部环境	①碳源规模；②碳源距离；③CO_2运输方式；④蕴矿状况

The methods and technologies in CO_2 geological storage site selection

二氧化碳地质储存场地选址所应用的技术方法

- 1. Information collection
- 2.Geological survey
- 3.Socio-economic conditions survey
- 4.Remote sensing interpretation
- 5.Geophysical exploration
- 6.Geological modeling
- 7.Numerical simulation

- 1.搜集资料
- 2.综合地质调查
- 3.社会经济条件调查
- 4.遥感解译
- 5.地球物理勘探
- 6.地质建模
- 7.数值模拟

Case1：Hechuan Chongqing

Background 背景

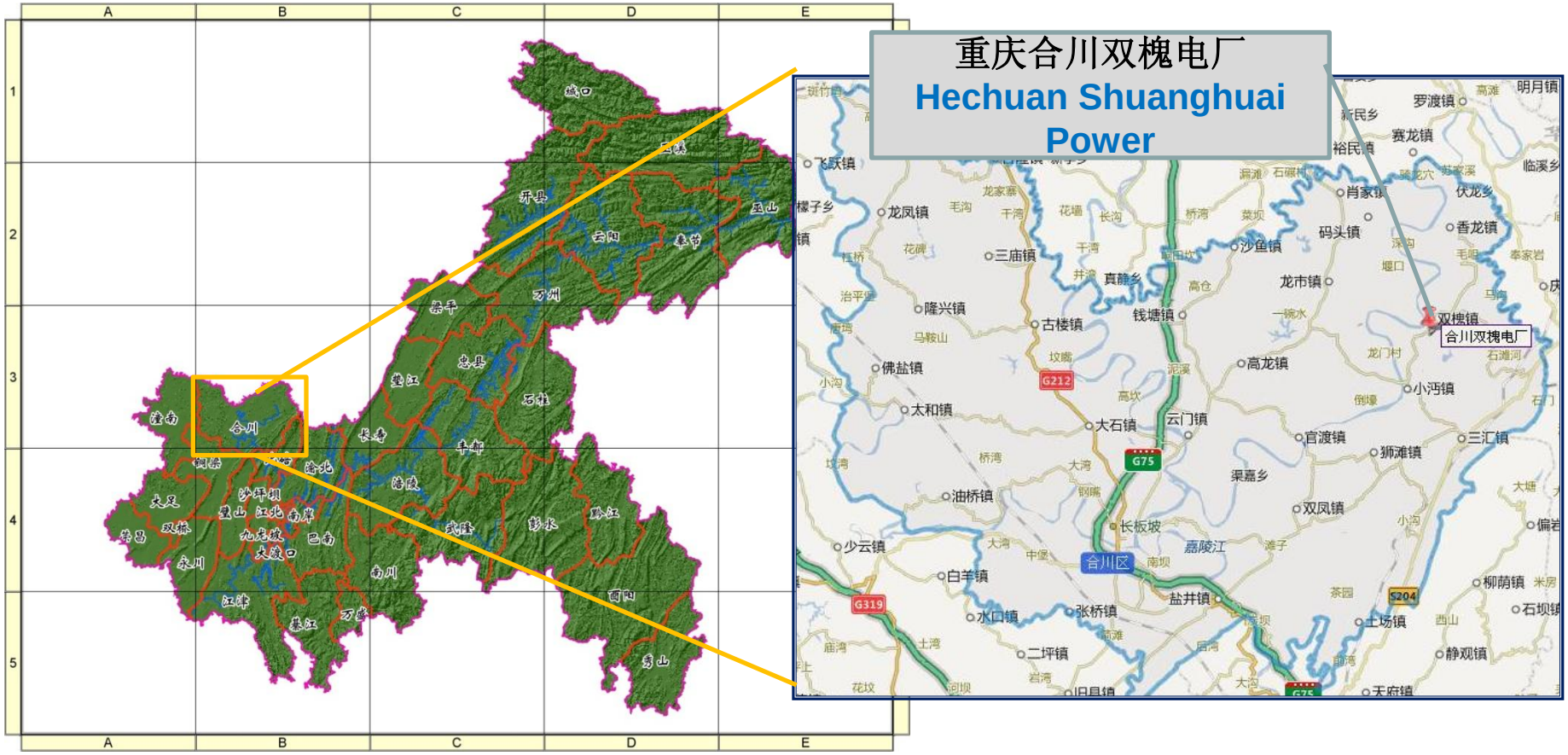
CPI万吨级二氧化碳捕集装置由中电投远达环保公司与合川发电公司共同研发建设，碳源来自重庆合川双槐电厂一期**1# 300MW**机组锅炉排放烟气。

The 10,000-ton level carbon capture plant of CPI was developed and set up jointly by CPI Yuanda Environmental Protection Engineering Co., Ltd. And Hechuan Power Generation Co., Ltd. Carbon resource came from the discharged flue gas of Chongqing Hechuan Power Plant Phase I unit # 1 300MW.

工作区地理位置　Location of Hechuan

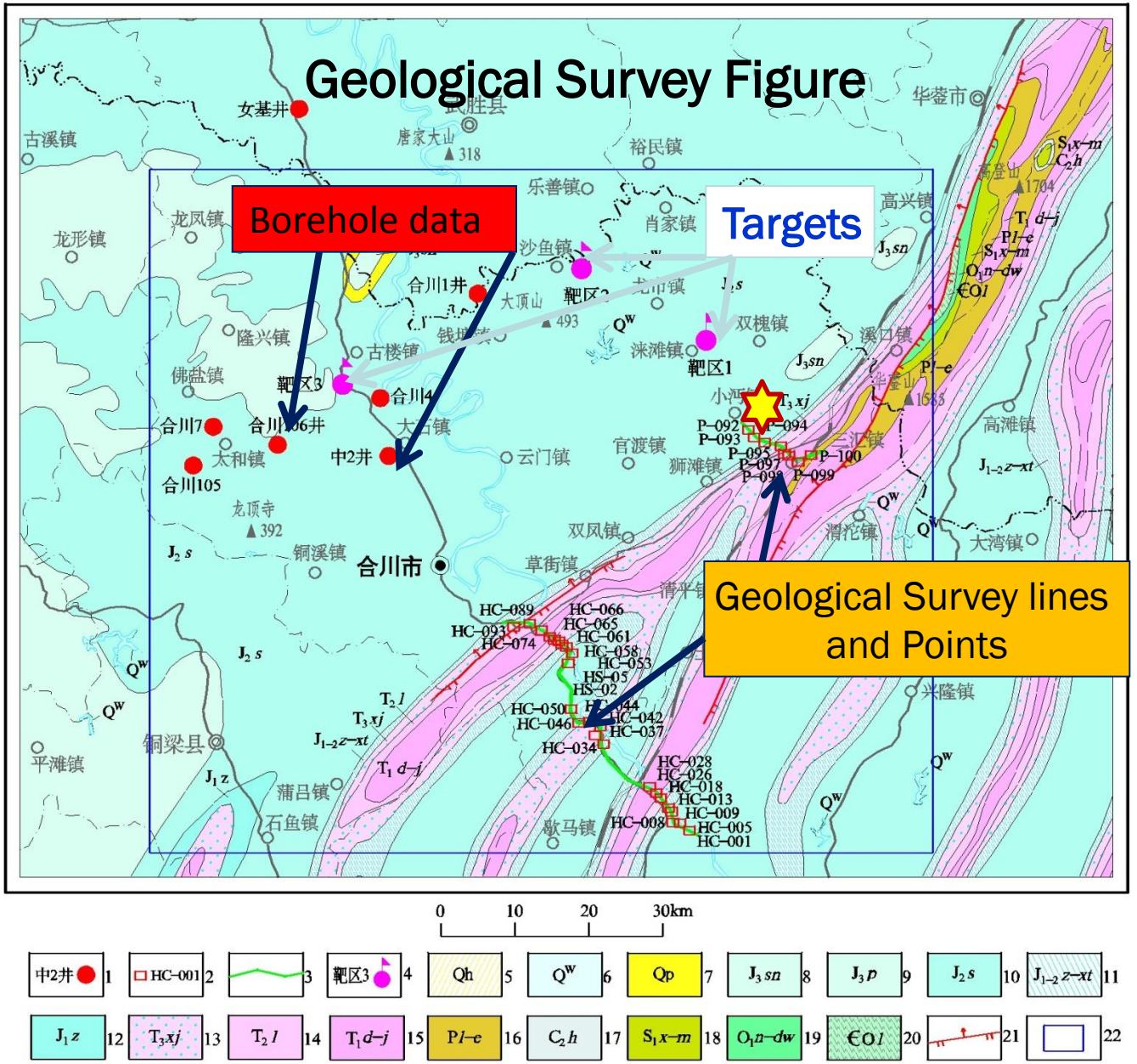
合川区，位于嘉陵江、渠江、涪江交汇处，是重庆北部地区中心规划城市。全区幅员面积2356 平方公里

Hechuan, located in the junction of the Jialing River, Qu River and Fu River, is the center city in the northern of Chongqing. The area is about 2356 square kilometers.



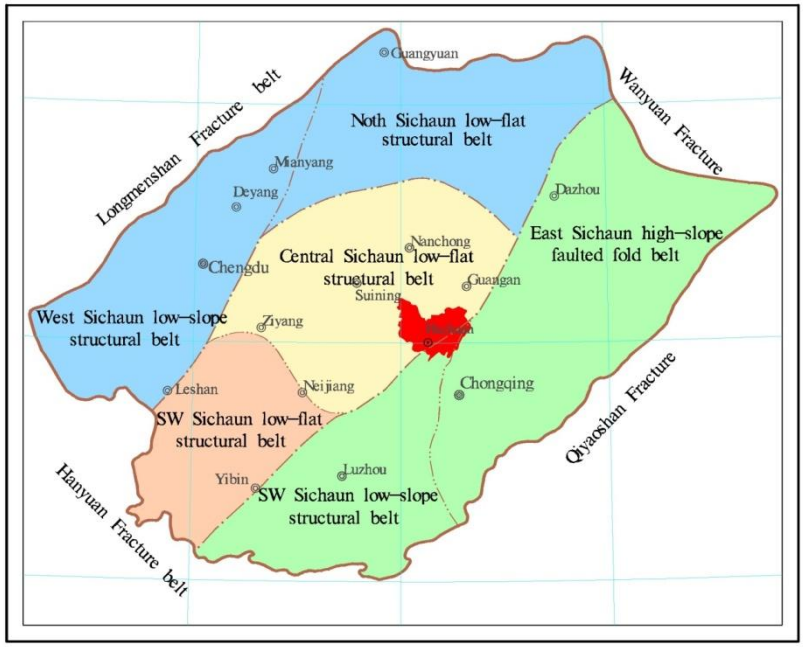
已开展的工作 The Work Already Done

- Data Collection
- Geological Survey
- Mapping



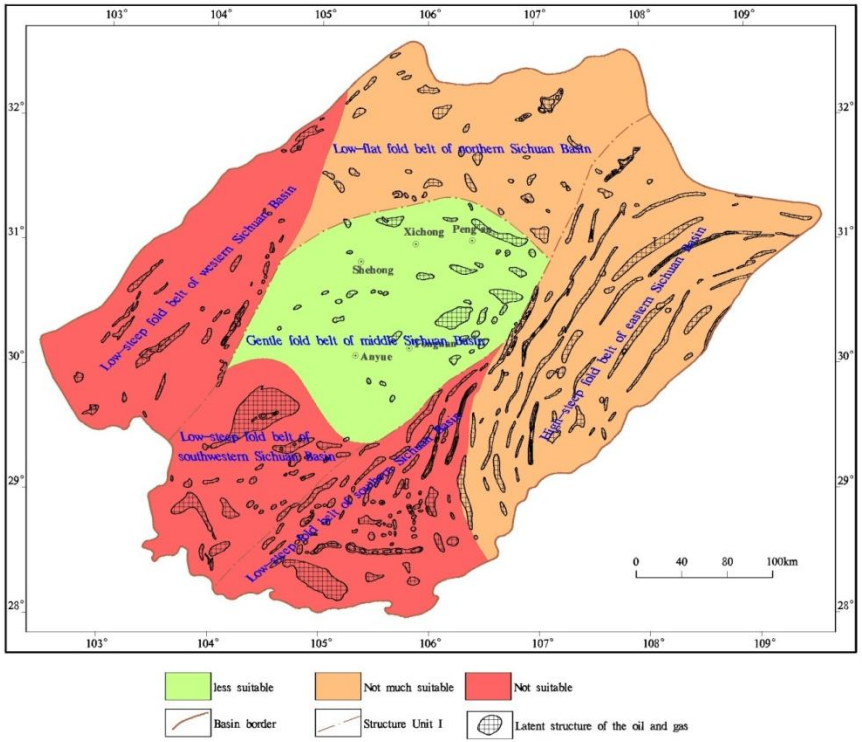
1. Structure condition for CO_2 geological storage in Hechuan

CO_2地质储存的有利构造



合川位于的位于四川盆地的川中平缓褶带二级构造单元内，具有较好的基础地质条件和地壳稳定性，研究程度高，CO_2地质储存潜力较大，是四川盆地最适宜开展CO_2地质储存的构造单元。

Hechuan locates Central Sichuan low-flat structural belt, With better basis of geological conditions , crustal stability, high research degree, and CO_2 geological storage potential, So it is the most suitable tectonic unit for CO_2 geological storage.



2. The reservoir and caprock

储盖层条件

川地区地层800~3500m埋深范围内可划分为8套储层和12套盖层。

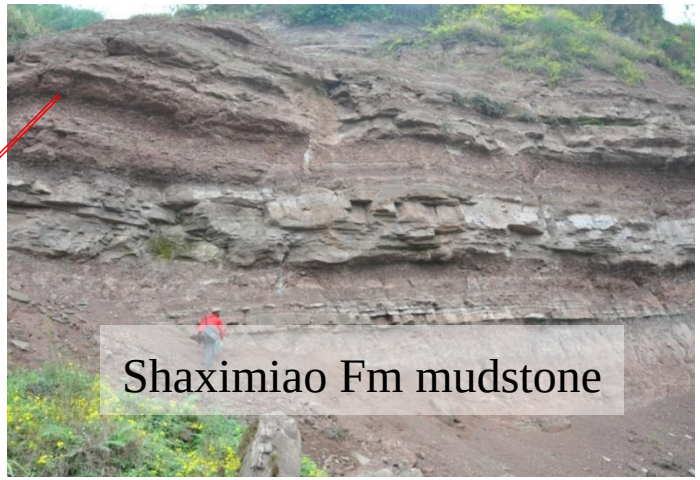
In Hechuan, within the range of 800 to 3500m depth, the stratum can be divided into 8 reservoirs and 12 caprockes

序号	储盖层	Reservoirs and Caprocks
盖1	沙溪庙组沙二段底部页岩和沙一段泥岩盖层	Shaximiao Fm mudstone And shale
储1	沙溪庙组沙一段细砂岩储层	Shaximiao Fm sandstone
盖2	凉高山组上段页岩、砂质页岩和下段泥岩盖层	Lianggaoshan Fm mudstone And shale
盖3	自流井组大安寨段的页岩	Daanzhai member of Ziliujing Fm shale
储2	自流井组大安寨段介壳灰岩储层	Daanzhai member of Ziliujing Fm shell limestone
盖4	自流井组马鞍山段泥岩	Maanshan member of Ziliujing Fm mudstone
盖5	自流井组东岳庙段页岩	Dongyuemiao member of Ziliujing Fm shale
盖6	自流井组珍珠冲段泥岩、砂质泥岩	Zhenzhuchong member of Ziliujing Fm mudstone
储3	须家河组须六段粉砂岩和中砂岩储层	the sixth member of Xujiahe Fm sandstone
盖7	须家河组须五段页岩、砂质页岩	the fifth member of Xujiahe Fm shale
储4	须家河组四段细砂岩和中砂岩储层	the fourth member of Xujiahe Fm sandstone
盖8	须家河组须三段页岩、砂质页岩。	the third member of Xujiahe Fm shale
储5	须家河组须二段细砂岩储层	the second member of Xujiahe Fm sandstone
盖9	须家河组须一段页岩	the first member of Xujiahe Fm shale
盖10	雷口坡组优质膏岩层盖层	Leikoupo Fm gypsum rock
储6	雷口坡组白云岩类储层	Leikoupo Fm dolomite
盖11	嘉陵江组石膏作为盖层	Jialingjiang Fm gypsum rock
储7	嘉陵江组粉细晶白云岩为主的储层	Jialingjiang Fm dolomite
盖12	飞仙观组飞四段页岩	Feixianguan Fm shale
储8	飞仙关组飞三段亮晶鲕粒灰岩储层	Feixianguan Fm limestone

2. The reservoir and caprock

典型地层岩性　Typical formation lithology

地层 界	系	统	组	段	厚度 (m)	剖面	储盖组合	岩性描述
	侏罗	中统	沙溪庙	沙二段	900			以紫红、深紫色泥岩为主，次为灰绿色、灰色粉砂岩，浅灰色细砂岩，底部为深灰色叶肢介页岩。
				沙一段	330			上部以深紫色泥岩、砂质泥岩为主，夹薄-中厚层状浅灰色细砂岩、泥质细砂岩；中部为中-厚层状灰绿色细砂岩与深紫色泥岩呈不等厚互层；下部以深紫、灰绿色泥岩为主，夹薄-中厚层状灰绿色粉砂岩、泥质粉砂岩；底部为灰色泥岩、粉砂岩、泥质粉砂岩及浅灰色细砂岩。



2. The reservoir and caprock

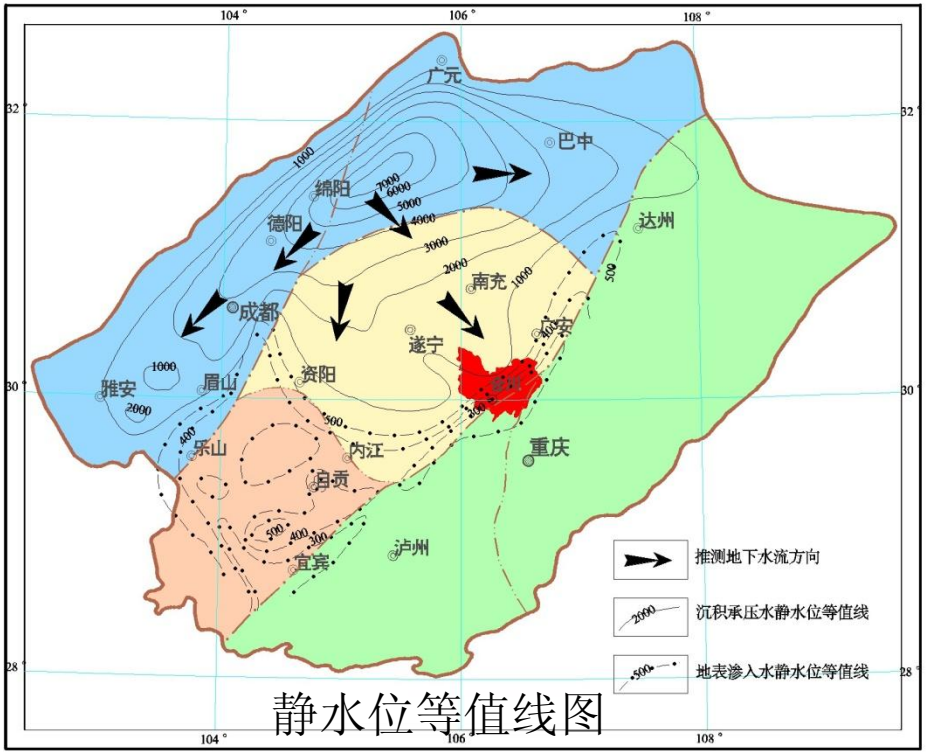
地层 界	系	统	组	段	厚度 (m)	剖面	储盖组合	岩性描述
		下统	凉高山	凉上段	50			上部以灰黑色页岩、砂质页岩为主夹灰色粉砂岩；下部为灰色、灰绿色粉砂岩。
				凉下段	40			中上部以泥岩夹灰绿色粉砂岩为主，底部为灰绿色粉砂岩。
			自流井	大安寨段	200			浅灰褐色介壳灰岩为主夹灰黑色页岩
				马鞍山段	100			上部为紫红、深紫色泥岩；中部灰绿色粉砂岩夹灰绿色泥岩、深紫色砂质泥岩；下部为灰绿色泥岩。
				东岳庙段	30			以灰黑色页岩为主夹灰黑色介壳灰岩。
				珍珠冲段	180			以深紫红色泥岩、深紫色泥岩、砂质泥岩为主，夹灰绿色粉砂岩、泥质粉砂岩；近底部为灰绿色泥质粉砂岩、泥岩、砂质泥岩。
	三叠系	上统	须家河	须六段	100			上部岩性以灰色、深灰色粉砂岩为主，夹灰黑色页岩；中下部以浅灰色细砂岩、粉砂岩、灰白色中砂岩为主夹深灰色页岩、砂质页岩；底部灰白色中砂岩。
				须五段	100			以深灰色、灰黑色页岩、砂质页岩为主夹灰色、浅灰色粉砂岩，中部及底部少夹薄层灰黑色砂质页岩、碳质页岩及黑色碳质页岩、煤层。
				须四段	110			上部为浅灰色细砂岩、灰白色中砂岩为主夹薄层灰黑色页岩；下部为灰白色细砂岩、中砂岩夹薄层灰黑色页岩，中部夹一层中厚层灰黑色页岩。
				须三段	60			以黑色页岩为主，次为深灰色灰质粉砂岩，近底部夹薄煤层；顶部为深灰色灰质粉砂岩；底部为灰黑色砂质页岩。
				须二段	90			以浅灰色、灰白色细砂岩为主，夹黑色、灰黑色页岩、砂质页岩。
				须一段	20			以黑色页岩、碳质页岩及灰黑色砂质页岩为主，夹灰色粉砂岩。
		中统	雷口坡	雷三段	110			上部主要为灰色致密及显微粒状石灰岩，含泥较重；下部以白云岩为主，夹灰岩，白云岩含泥质重，其中夹薄层硬石膏及白云质页岩
				雷二段	200			上部以厚度较大的白云质硬石膏层组成本段主要岩性，其中夹白云岩；下部主要为灰色白云岩及含硬石膏的白云岩
				雷一段	60			主要为灰岩夹白云岩，互层产出

2. The reservoir and caprock

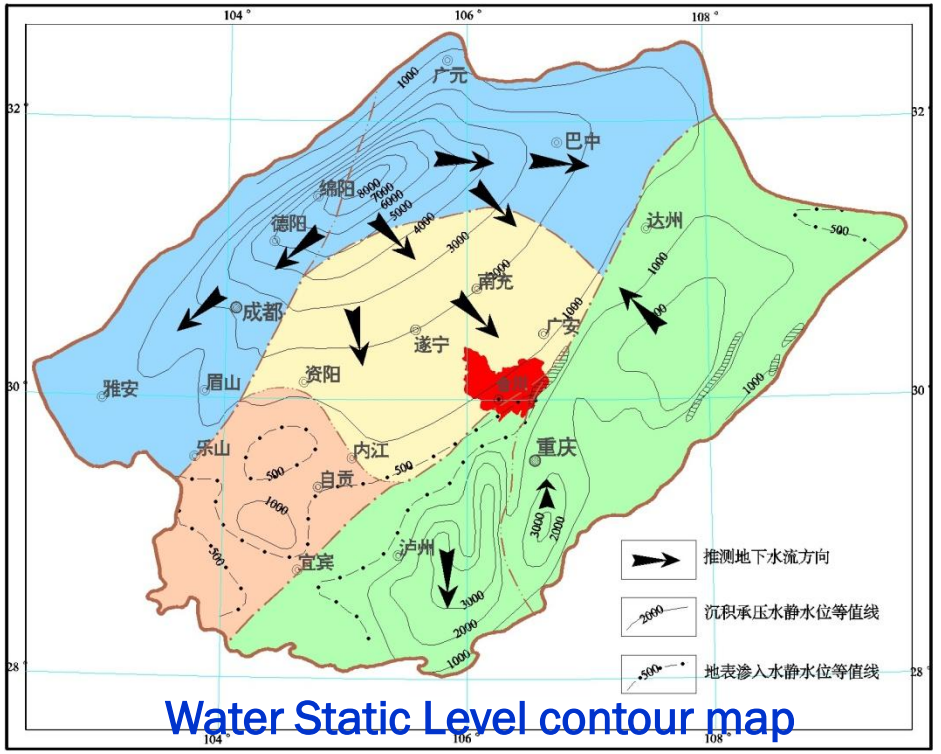
地层 系	统	组	段	厚度 (m)	剖面	储盖组合	岩性描述
	下统	嘉陵江组	嘉五段	160			上部为深灰色白云岩，中部灰白色硬石膏夹深灰色白云岩，底部深灰色灰岩
			嘉四段	150			灰白色硬石膏夹白云岩
			嘉三段	140			深灰色灰岩
			嘉二段	130			褐灰色白云岩夹石膏
			嘉一段	210			灰色、深灰色灰岩
		Feixianguan	飞四段	50			紫红色灰质页岩
			飞三段	130			黑灰色灰色灰岩

3.Hydrogeology

水文地质条件



静水位等值线图



Water Static Level contour map

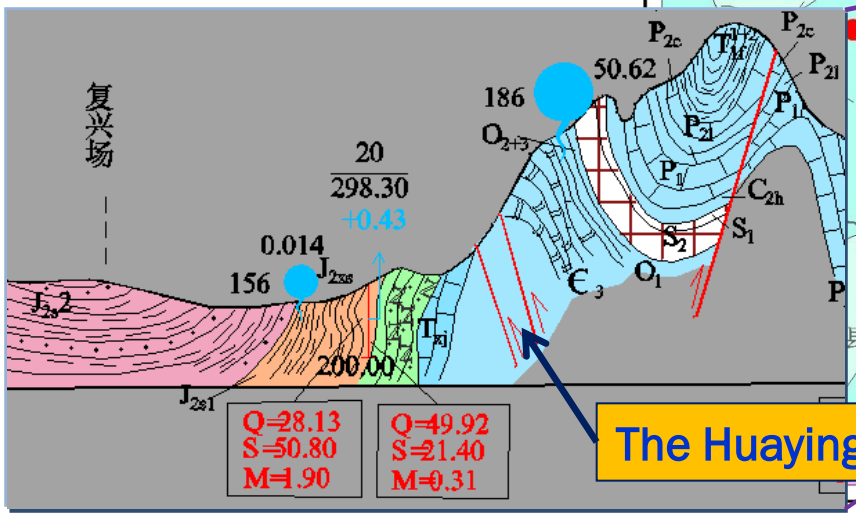
合川地区的处于沉积承压水的水力系统和地表渗入水的水力系统的过渡带，两系统使得合川地区深部咸水层保持了水力平衡，具有水力封堵作用，有利于深部咸水层CO_2地质储存；

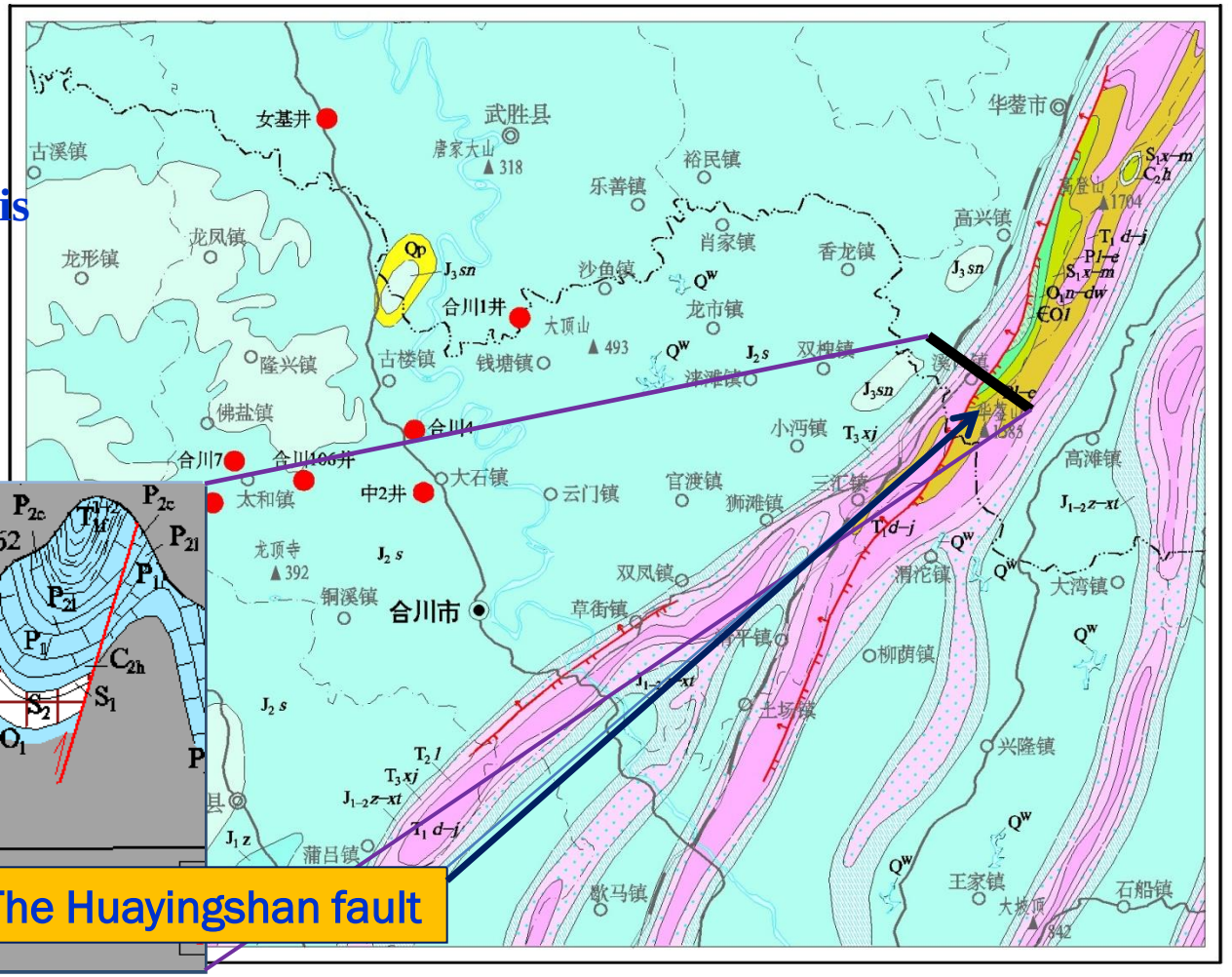
Hechuan is in the transition zone of pressure hydraulic systems and surface water infiltration water to keep hydraulic balance, with hydrodynamic trapping for CO_2 geological storage.

3.Hydrogeology

华蓥山大断裂是区内的一条主要断裂构造，具有多个分支的断层组，具叠瓦状逆冲断层性质

The Huayingshan large fault is a major fault structure in the region, a group of faults with multiple branches, which are imbricate thrust faults



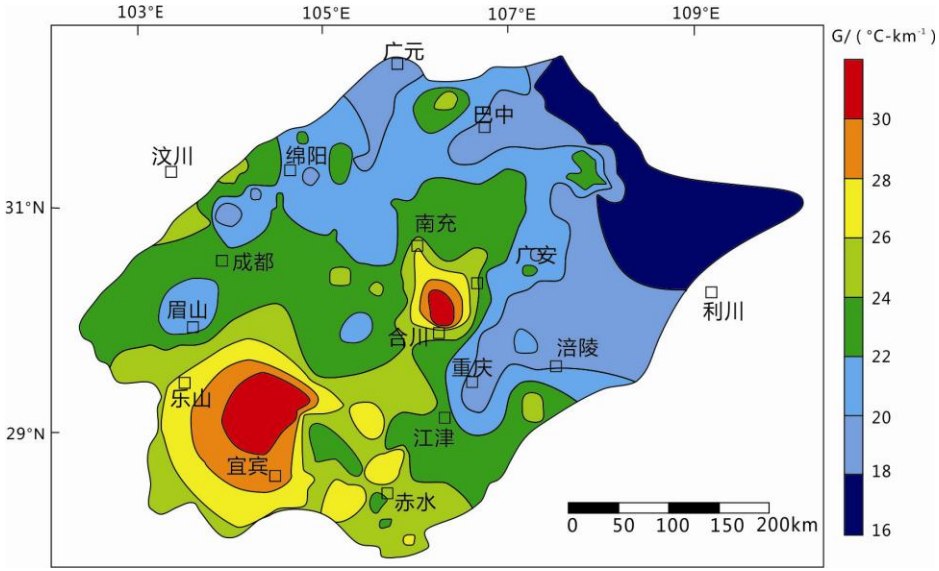


华蓥山断层属于逆断层，其西侧下盘具有较好的阻水性质，具有断层封闭作用，

The Huayingshan fault is thrust , the west of its footwall has good impermeability, with fault sealing effect for CO2 geological storage.

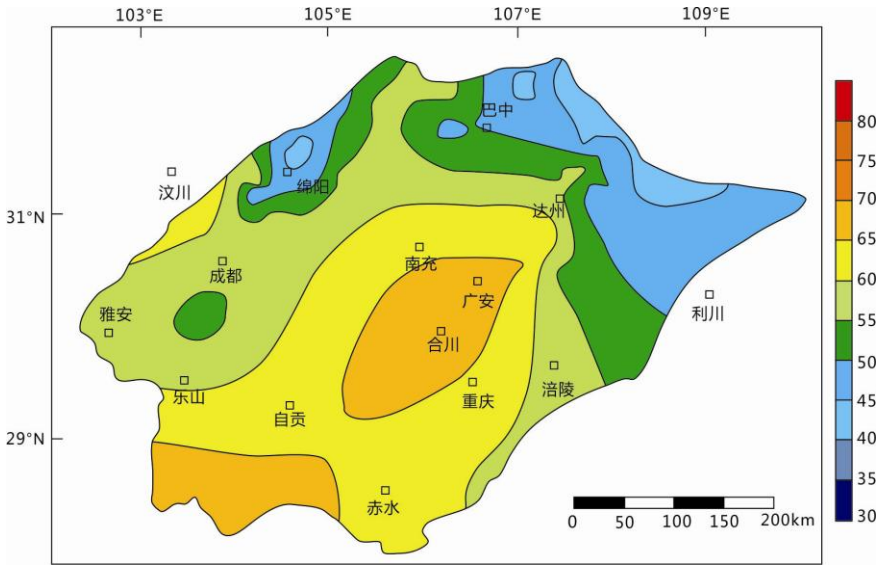
3. Geothermal

Geothermal
地热地质条件



四川盆地地温梯度等值线图

Geothermal gradient contour map of Sichuan Basin



四川盆地大地热流等值线图

Geothermal heat flow value contour map of Sichuan Basin

合川地区地温梯度介于2.2~2.6℃/100m；大地热流值介于65~70mw/m^2，地热地质条件基本适宜CO_2地质储存。

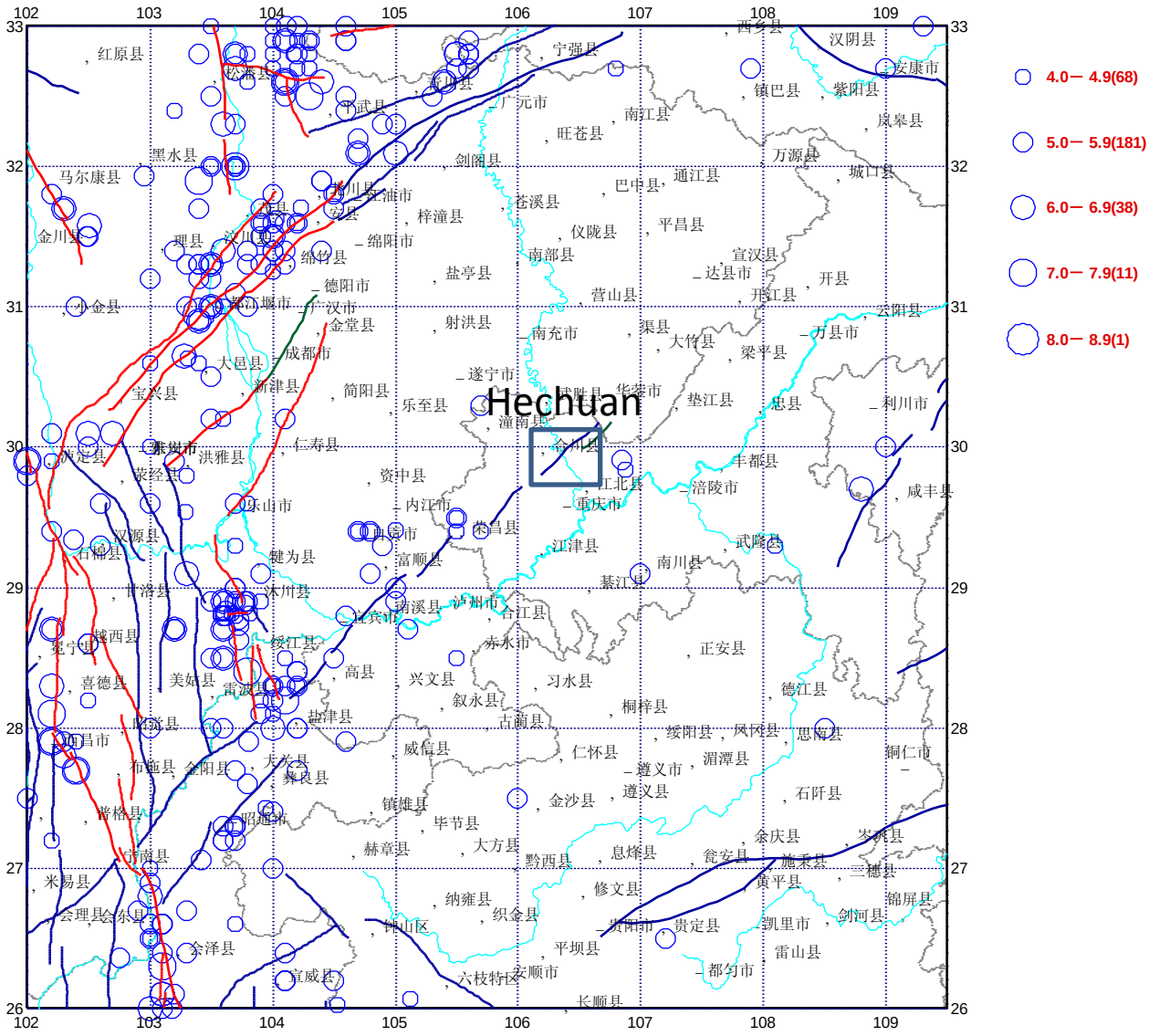
In Hechuan, geothermal gradient is 2.2~2.6℃/100m; and geothermal heat flow value is 65~70MW/m^2, which are basically suitable for CO_2 geological storage.

5. Geological security

地质安全性

- 合川地区西北部无活动断层
- 无火山活动与地质活动痕迹记录，
- 地处强震围空区，没有发生过4级以上地震，且距离强震源区较远，地壳稳定性好；

- **With not active faults in Hechuan northwest**
- **With not volcanic activity and geological activity records**
- **there has not been more than M4 earthquake in Hechuan, and far from the strong earthquake areas**
- **It is crustal stability for CO_2 geological storage**



四川盆地及周缘中强地震分布图（-26-2010.12，M≥4¾）

5. Geological security

已有钻孔影响　Existing Borehole Effect

由于当地油气资源勘探开采，存在废弃井和部分正在作业的天然气开采井，可能成为CO_2地质储存的泄露通道，应对已有钻井进行更详细调查，并采取措施避免CO_2泄露。

Due to oil and gas exploration, there are some abandoned borehole and natural gas extraction borehole, which may be a leakage channel of CO_2 underground, so we should do more work to investigate the existing borehole, and to take measures to stop CO_2 leakage.

6. CO_2 geological storage Capacity

CO_2地质储存潜力

经初步计算，合川地区在面积为100km^{2}储存场地内，深部咸水层中二氧化碳地质储存量总量为51×10^{6}t，其中砂岩储层的储量为30×10^{6}t，碳酸盐岩储层的储量为21×10^{6}t。若以每年100万吨的注入量计算，可满足使用30年以上。

In a storage site with 100km^2 area in Hechuan, CO_2 geological storage Capacity in Deep Saline Aquifers is about 51×10^{6}t, and 30×10^{6}t in sand stone reservoir, 21×10^{6}t in carbonatite reservoir. If store 1 Million tons per year, the site can be used more than 30 years.

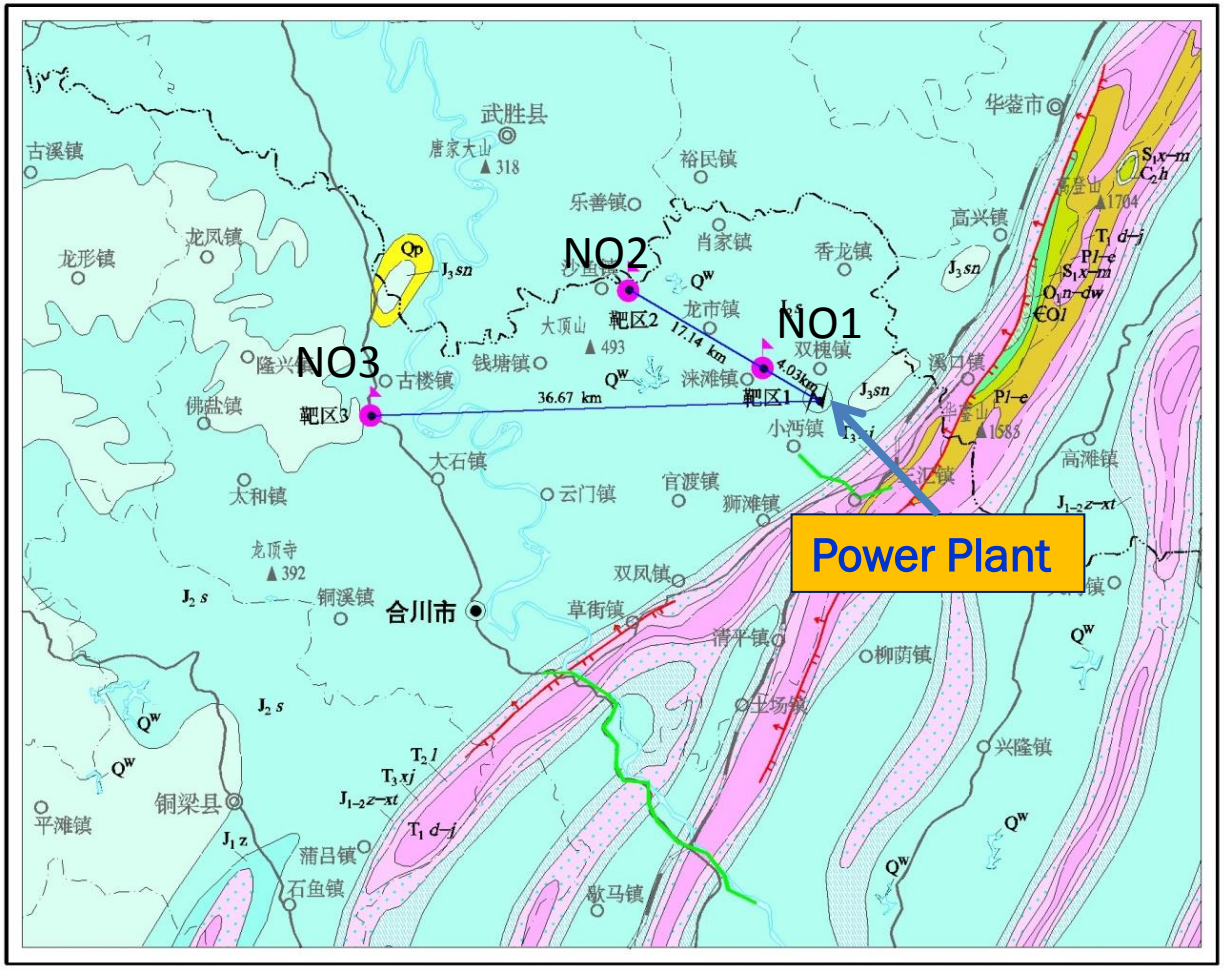
7. Socio-economic and environmental conditions

社会经济条件

运输方式

- 所选择的三处靶区与合川双槐电厂的距离不超过40km，公路距离不超过100km
- 对于大规模的CO_2输送，可采用管道运输

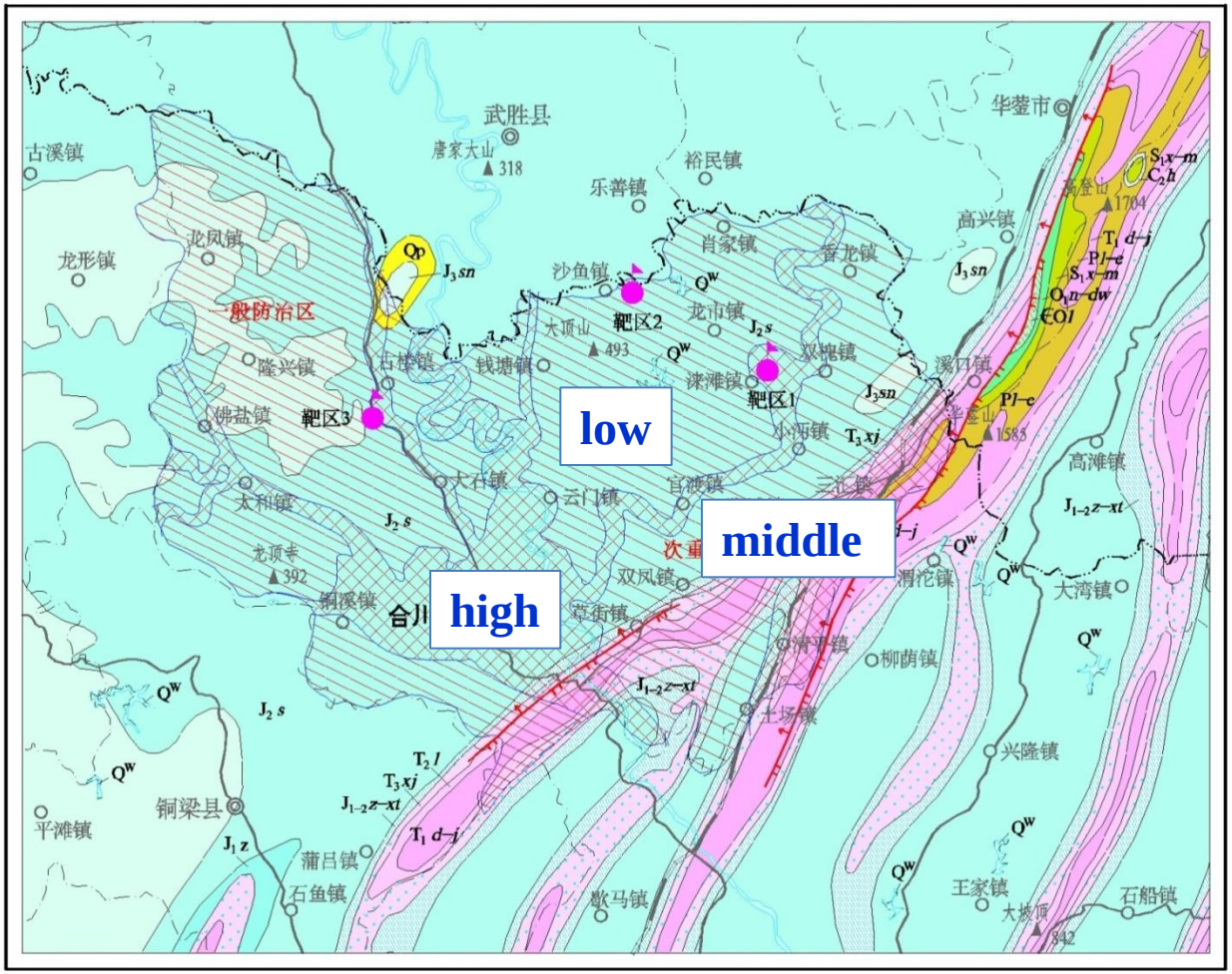
- **Distance of the chosen three targets and the Hechuan Shuanghuai plant no more than 40km, the road distance does not exceed 100km**
- **Pipeline transportation can be used for large-scale CO_2 transport**



7. Socio-economic and environmental conditions

地质灾害

- 合川划分为3类地质灾害防治区：重点防治区、次重点防治区和一般防治区；
- 除了目标靶区1外，另两处靶区都在合川的一般地质灾害防治区内，地质灾害对CO_2地质储存影响较小



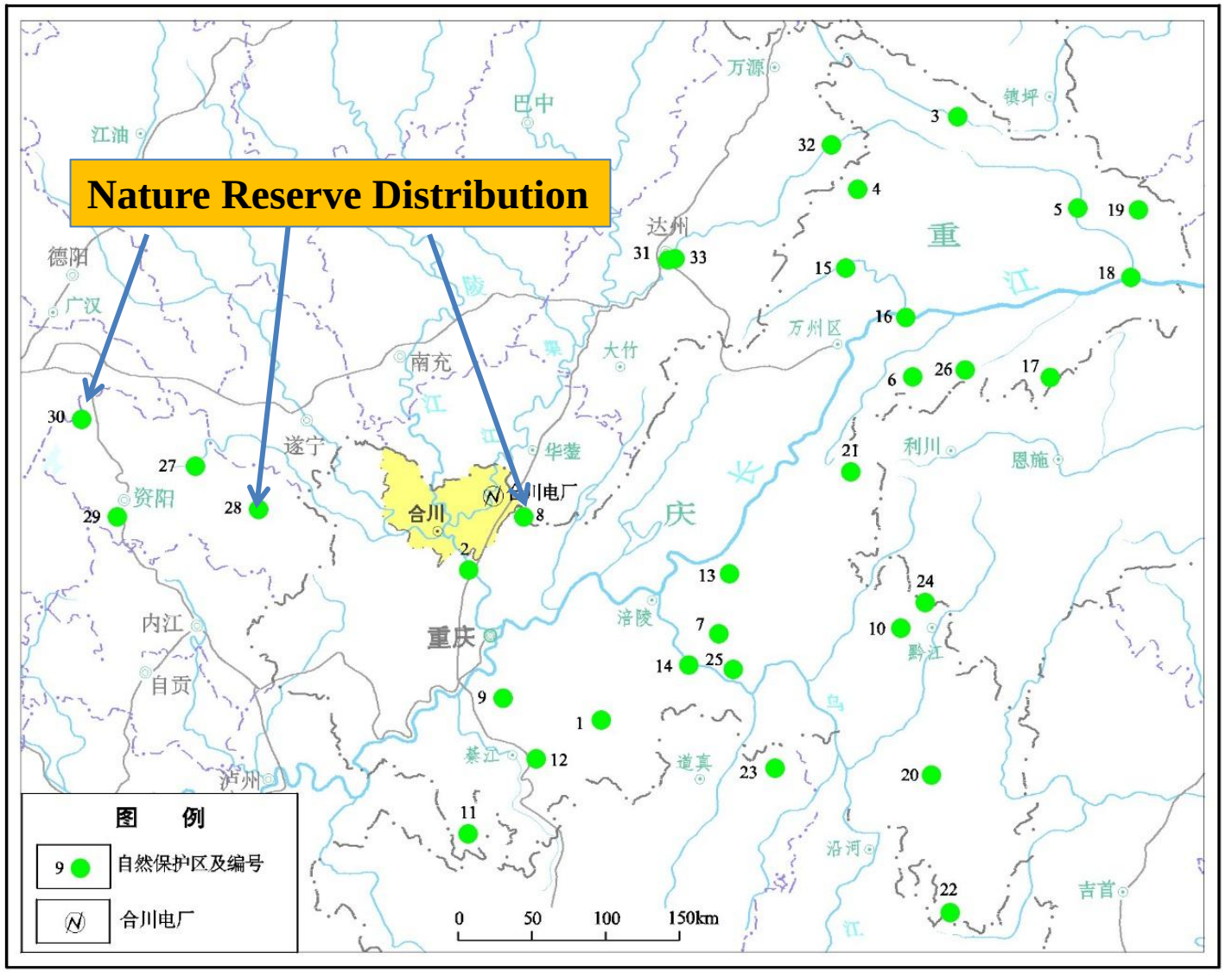
- There are three types of geological disaster zone: high, middle and low.
- Except the target 1, the other two are in the low geological disaster zone, with little effect on CO_2 geological storage

7. Socio-economic and environmental conditions

自然保护区分布

目标靶区不在自然保护区之内，进行CO_2地质储存对周边的自然保护区不会产生影响；

Targets are not within a nature reserve, and CO_2 geological storage will not impact any nature reserve

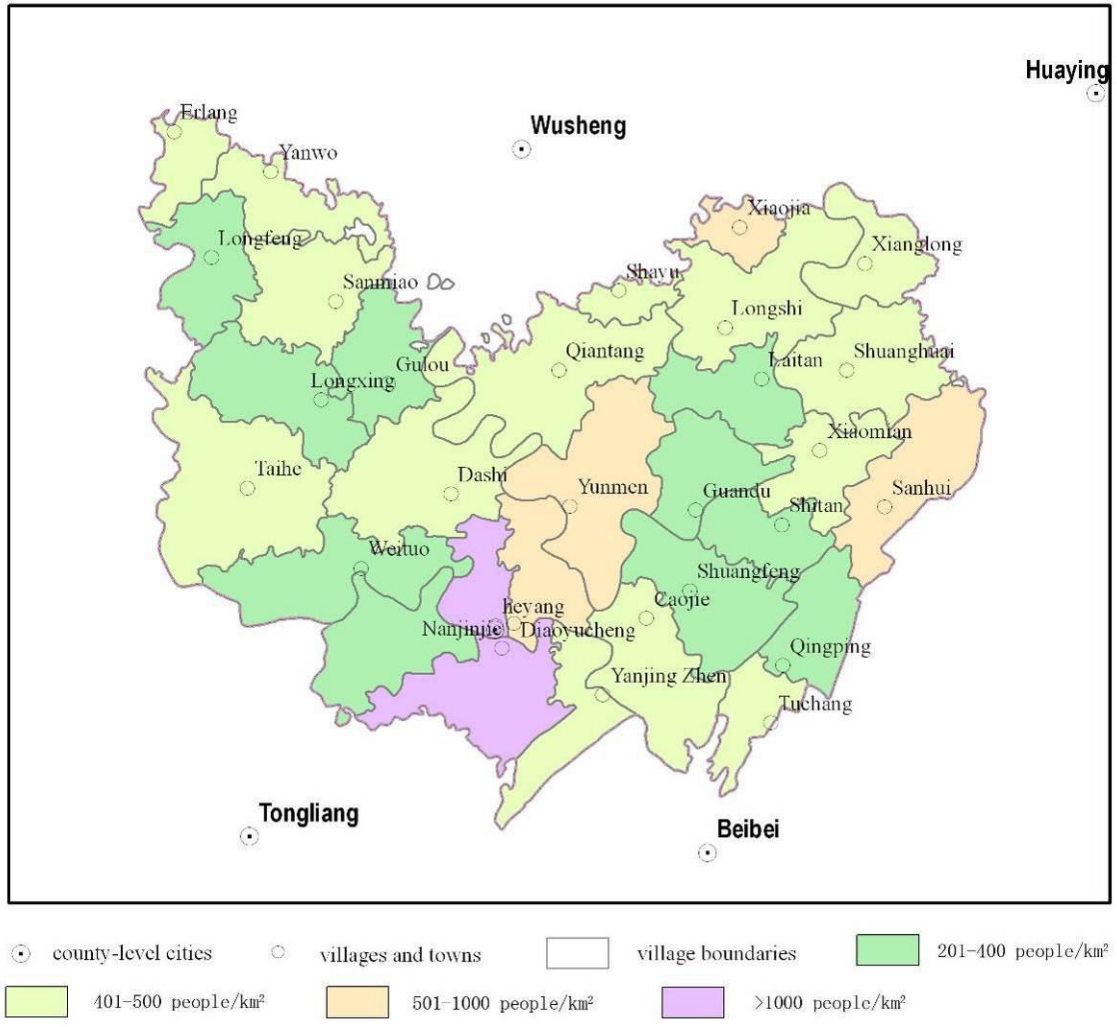


7. Socio-economic and environmental conditions

人口分布

The township population density of Hechuan

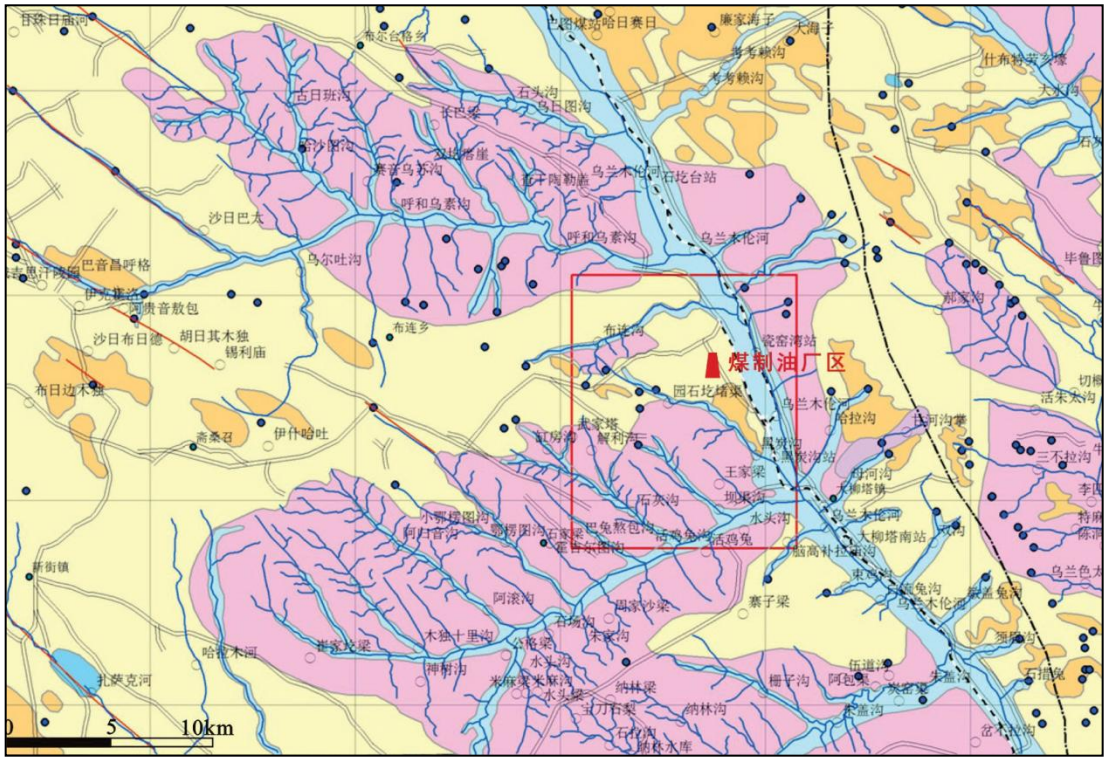
合川区各乡镇人口密度分布图



Case 2：CCS pilot-project in Ordos

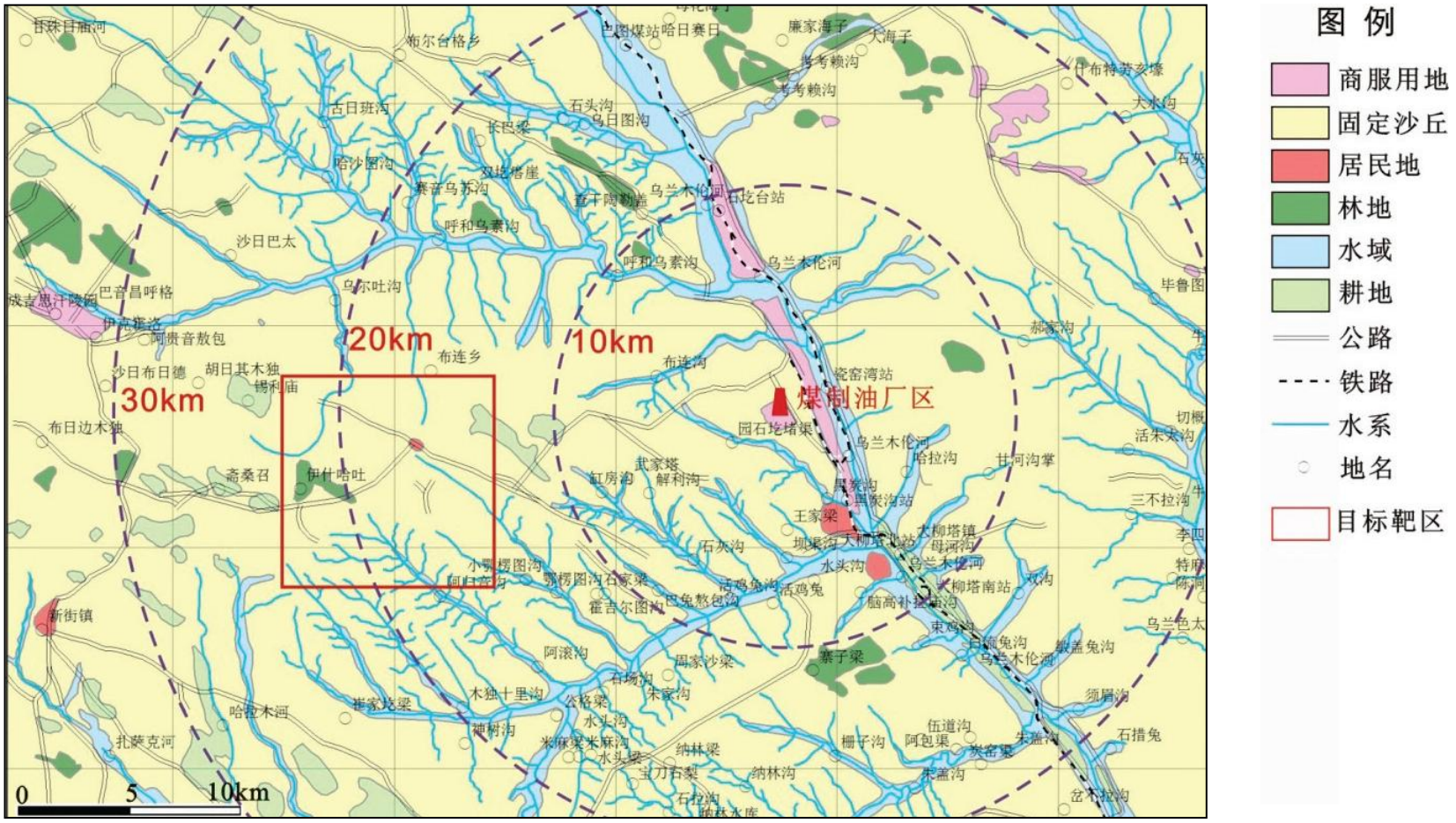
Background 背景

- 2010年，中国地质调查局水文地质环境地质调查中心与神华煤制油化工有限公司合作，共同实施了鄂尔多斯二氧化碳地质储存示范工程，这是世界首个煤基全流程深部咸水层CO_2地质储存示范工程，灌注目标10万吨/年，2011年1月开始试注。截止2013年5月底，示范工程已成功灌注CO_2 12万余吨。
- **Cooperation with Shenghua Group, Center for Hydrogeology and Environmental Geology Survey developed the CCS pilot project, first coal-based CCS pilot project in deep saline aquifers in the World，Injection target:100×10³t/，Injection test from Jan, 2011. As of the end of May 2013, the project have been successfully injected CO_2 12**



Remote sensing interpretation

遥感解译



目标靶区及周边的碳源分布及土地利用现状图

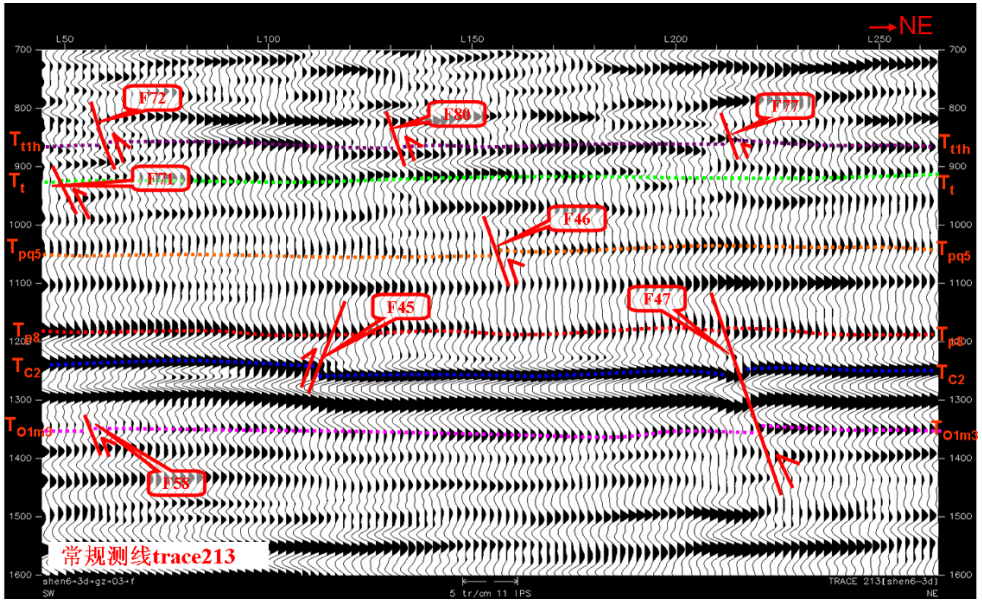
Carbon distribution and land use in target area and surrounding

Geophysical exploration 地球物理勘探

为深入了解调查区地表下500～3000m深度区间CO_2地质储存储盖层地质及空间展布特征，在场地选址综合地质调查和遥感解译的基础上，开展了三维地震勘探工作。

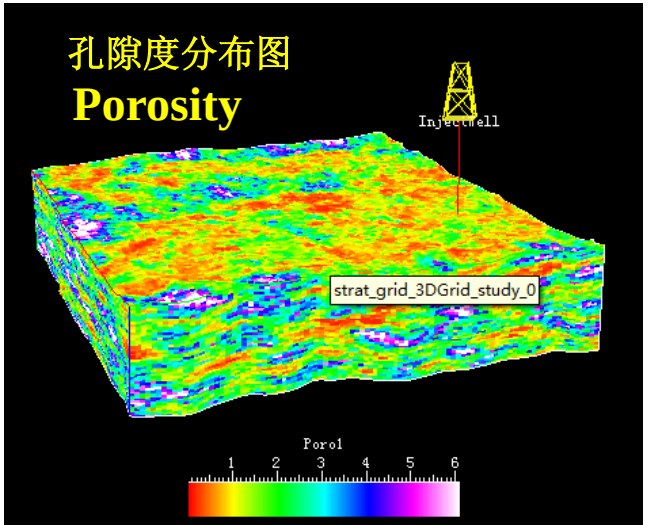
For understanding spatial distribution characteristics of caprocks and reservoirs of the site under the surface 500 ~ 3000m depth, after the comprehensive geological survey and remote sensing interpretation, they carried out three-dimensional seismic exploration work.

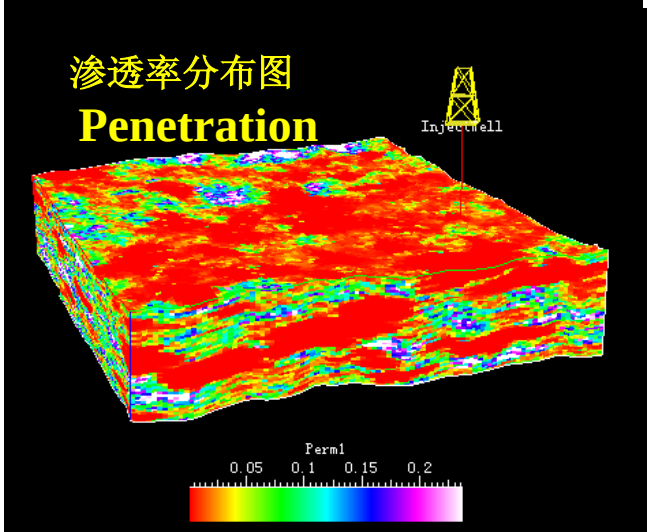
- 基于三维地震勘探数据，查明了所选区内断裂构造的分布情况和地层状况，并建立了地质模型
- **Based on the 3D seismic exploration data to identify the distribution of fault structure and stratigraphic position in the chosen site, and the establish the geological model**



断裂分布剖面图

Cross-sectional of seismic exploration to show the fault distribution

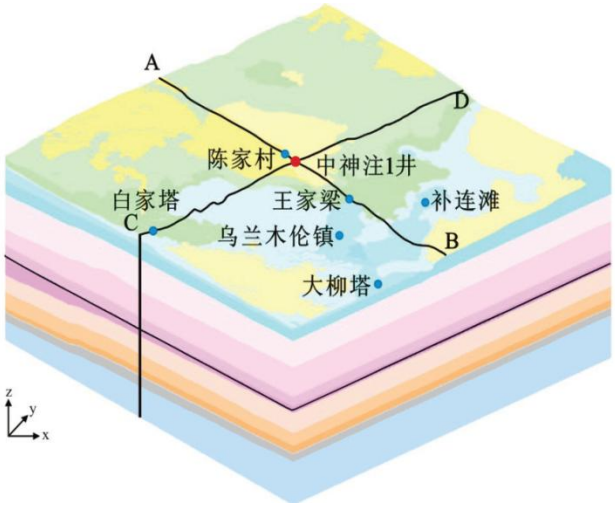


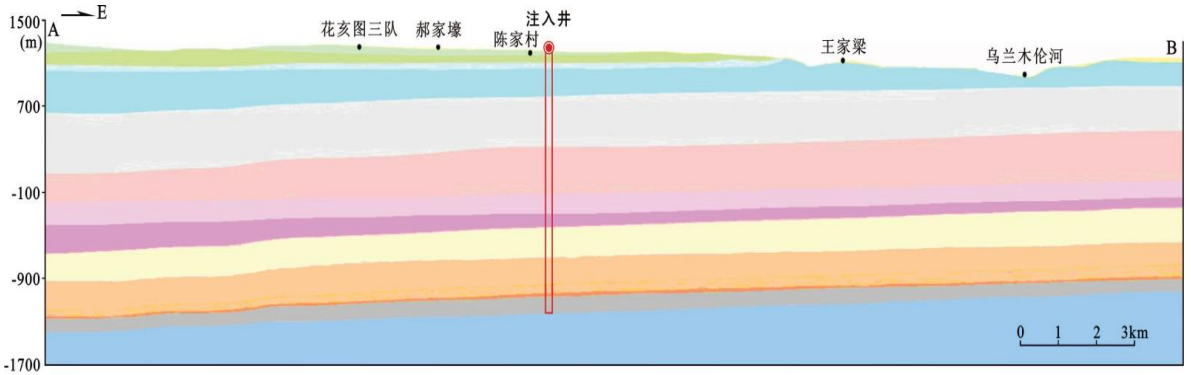


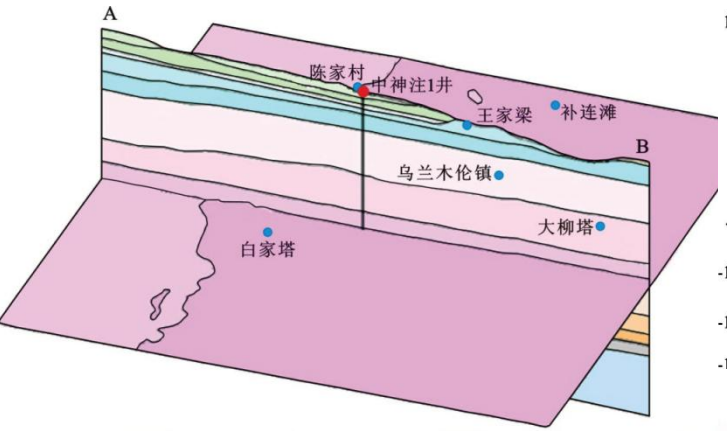
3D Geological Model　　三维地质建模

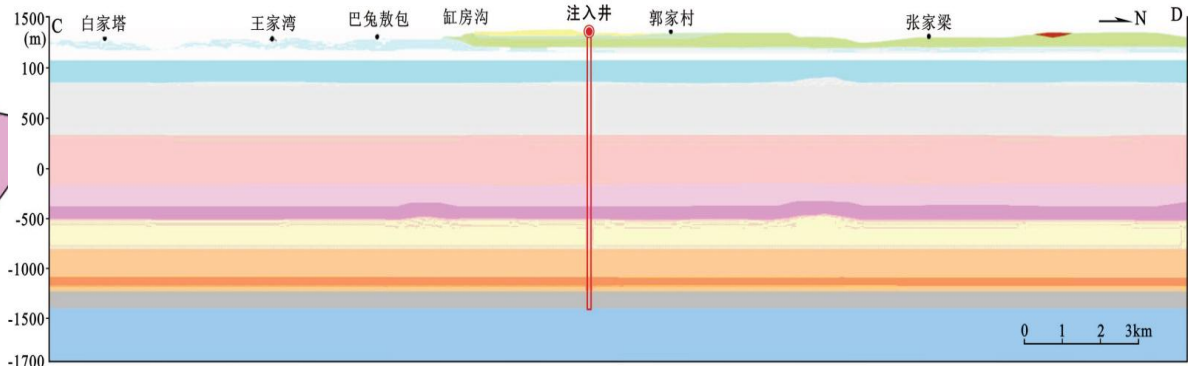
Based on the demonstration project site geophysical exploration, drilling and testing a large number of core samples from experimental data, geological model expresses the structural information and properties characteristic of formation.

地质模型是基于示范工程场地地球物理勘探、钻探和大量的岩心样品测试试验资料，对地层结构信息和属性特征的表达。









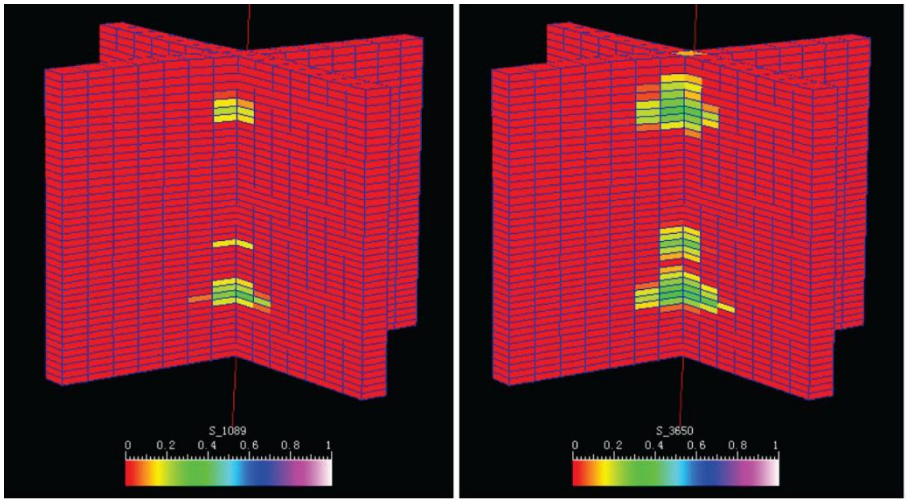
Numerical simulation 数值模拟

基于场地地质模型的建立，通过CO_2地质储存进行数值模拟，对CO_2地下动态运移进行预测，为工程实施提供依据。

Based on site geological model, through CO_2 geological storage numerical simulation, forecasting CO_2 dynamic migration, to provide a basis for the project.

CO_2 injection capacity and space transport modeling in reservoirs

储层CO_2注入能力和空间运移模拟

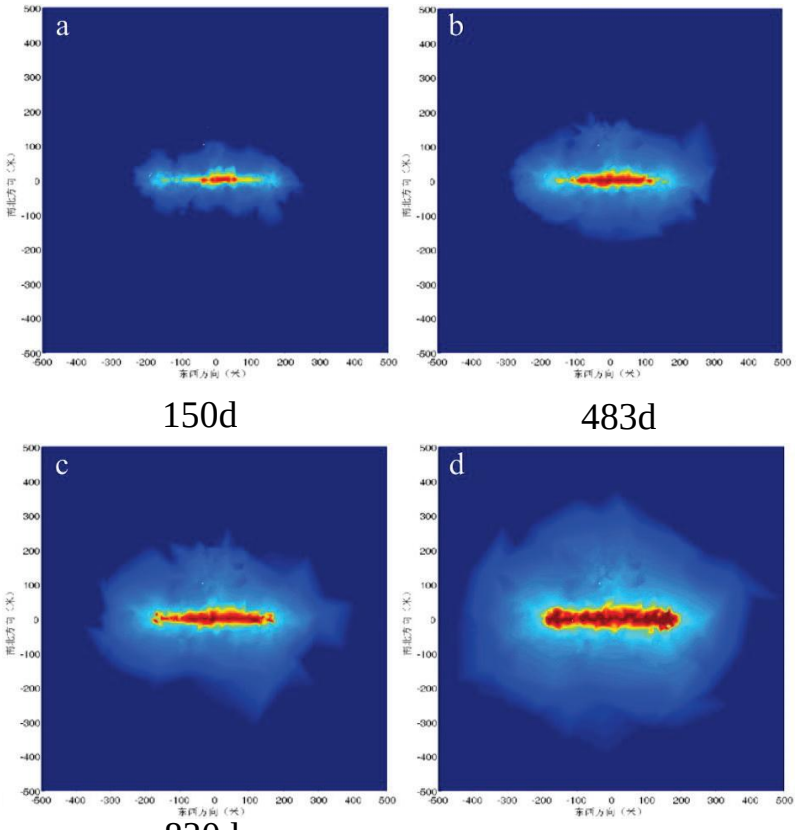


3 years later
注入3年后

10 years later
注入10年后

CO_2 Plume migration front forecast

CO_2羽状体运移前缘预测



150d

483d

830d

1825d

Conclusions

- **The work of potential and suitability assessment of CO_2 geological storage is divided into five stages in China:**
  - Regional scale for predicted potential evaluation,
  - Basin scale for inferred potential evaluation,
  - Target scale for controlled potential evaluation,
  - Site scale for basic capacity,
  - Project capacity for injection scale
- **中国的二氧化碳地质储存潜力与适宜性评价工作分为5个阶段：**
  - 区域级预测潜力评价阶段
  - 盆地级推定潜力评价阶段
  - 目标区级控制潜力评价阶段
  - 场地级基础储存量评价阶段
  - 灌注级工程储存量评价阶段

Conclusions

- **First, second and third stages are the planning site selection, The fourth stage is project site selection. In the progress of site selection, served as a transition, target area selection and assessment is very important.**
- 第一、二、三阶段为规划选址阶段，第四阶段即工程选址阶段，在整个场地选址过程中，目标靶区的选取与评价将是一个非常重要的阶段，具有承上启下的作用。
- **Firstly, criteria system of target selection for CO_2 geological storage should be set up, which is divided into geological safety, storage size, social environmental risk and economic suitability of four index layer, and contains 44 indicators to be evaluated.**
- 目标靶区的选取与评价首先要建立一套完善的评价指标体系。可划分为地质安全性、储存规模、社会环境风险和经济适宜性4个指标层，包含了44个指标来进行评价。

- **In the progress of site selection, the methods and technologies in CO_2 geological storage site selection:**
  - 1. Information collection
  - 2.Geological survey
  - 3.Socio-economic conditions survey
  - 4.Remote sensing interpretation
  - 5.Geophysical exploration
  - 6.Geological modeling
  - 7.Numerical simulation

- **在储存场地选址过程中，所应用的技术方法包括：**
  - 1.搜集资料
  - 2.综合地质调查
  - 3.社会经济条件调查
  - 4.遥感解译
  - 5.地球物理勘探
  - 6.地质建模
  - 7.数值模拟

The methodology of CO_2 geological storage site selection is not Perfect, we still accomplish much.

COME ON！！！

中国的二氧化碳地质储存场地选址方法体系尚有待完善，我们仍大有作为。加油！！！

Thanks for your attention!