中国地质调查局
CHINA GEOLOGICAL SURVEY

Research Progress of CAGS3-TASK3: Potential Evaluation of CGUS in the Junggar Basin and Early Demonstration Opportunities in Eastern Junggar

Yujie Diao

Center for Hydrogeology and Environmental Geology Survey
China Geological Survey

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cags China Australia Geological Storage of CO_2
中澳二氧化碳地质封存

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1. Background

- 中澳二氧化碳地质封存项目（CAGS 3）: China Australia Geological Storage of CO_2 (Phase 3)
- 中国地质调查局二级项目（CGS）: Geological Survey of CO_2 Geological Storage in the Junggar and Other Basins（2016-2018）

中国地质调查局
水文地质环境地质调查中心

中国科学院武汉岩土力学研究所
Institute of Rock and Soil Mechanics, Chinese Academy of Sciences

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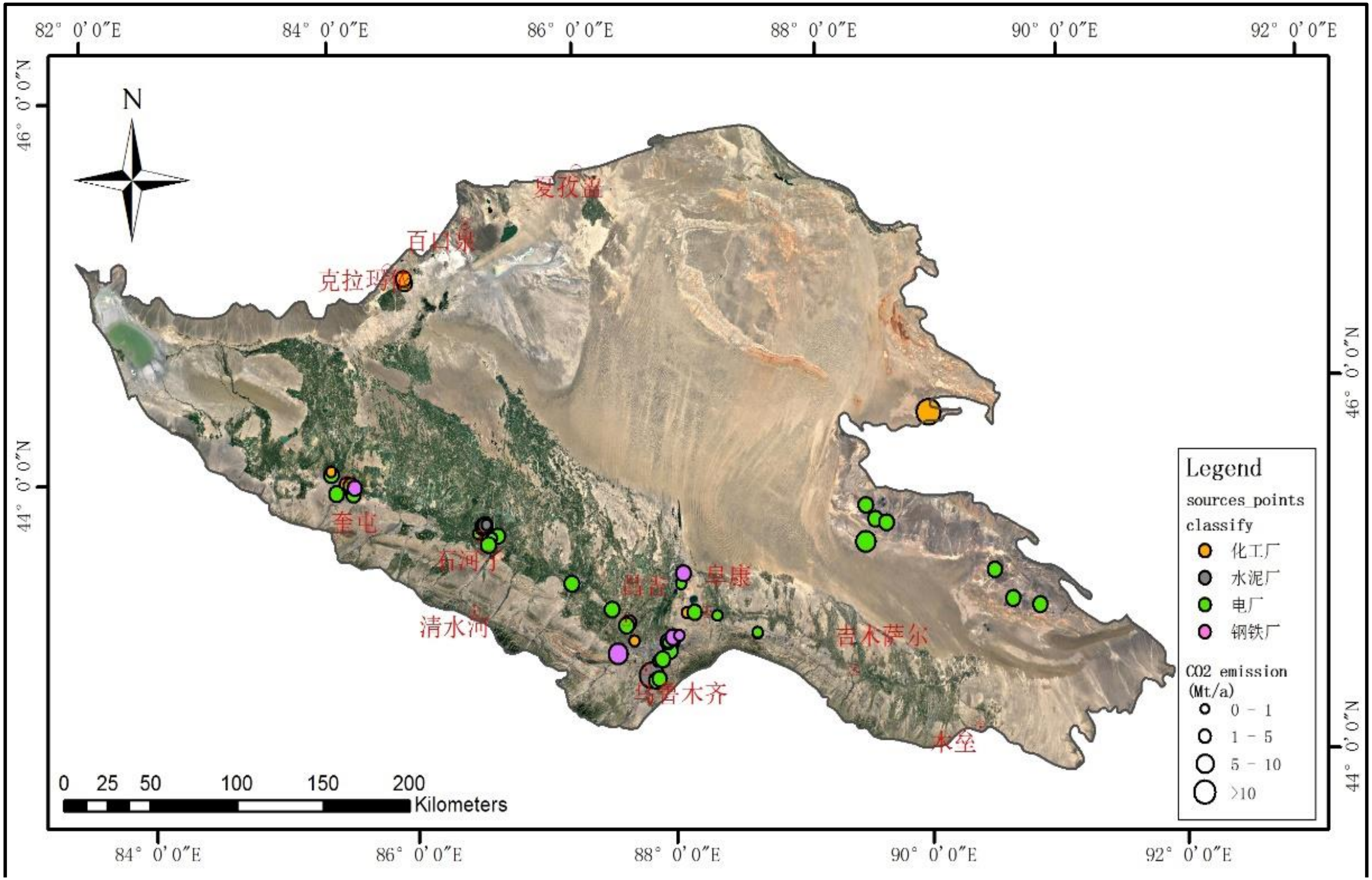
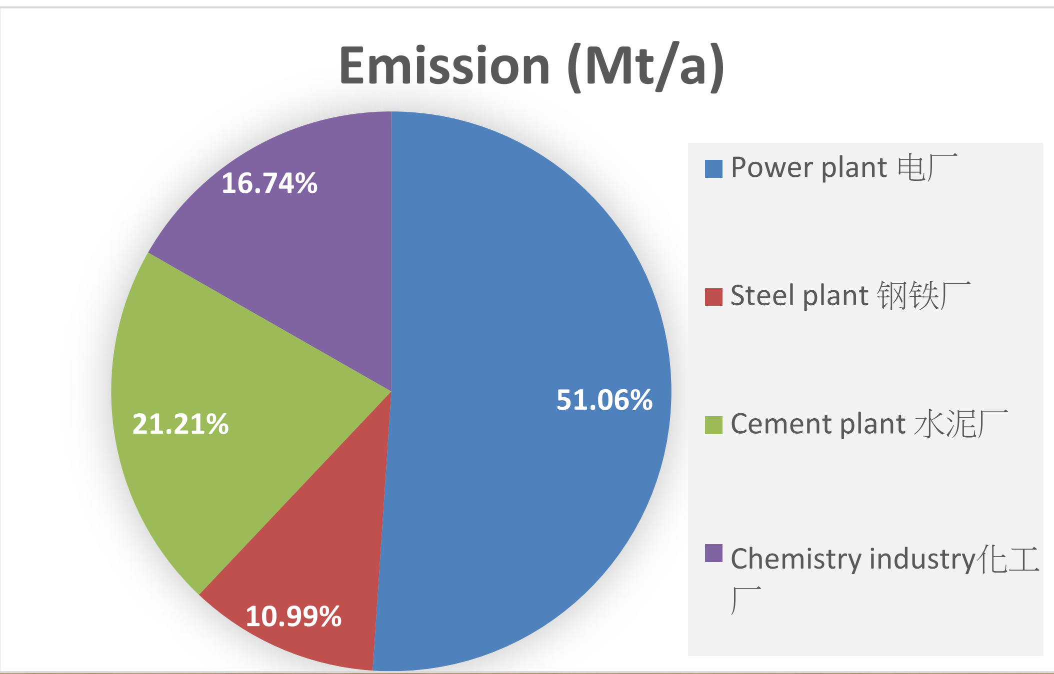
2 CO2 emission sources in the Junggar Basin



- 碳源主要分布在盆地南缘，乌鲁木齐、石河子和奎屯地区。
- CO2 emission sources are mainly distributed in the southern basin, especially Urumchi, Shihezi and Kuitun.

2 CO2 emission sources in the Junggar Basin

Class 类别	Amount 数量	Emission 排放量（Mt/a）
Power plant 电厂	32	67.51
Steel plant 钢铁厂	5	14.53
Cement plant 水泥厂	5	28.05
Chemistry industry 化工厂	12	22.13
Total 合计	54	132.22



- 碳源分布特点:
  - 共计54处，排放总量132.22 Mt/a ；
  - 排放源以电厂为主，排放量大，占总排放量(51.06%)；
- CO_2 emission points:
  - 54 sources with 132.22 Mt/a emissions
  - Mainly are power plants, accounting for 51.06%

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3.1 Potential evaluation of CGUS

CO_2 Geological Utilization and Storage (CGUS) technologies

CO2地质利用与封存技术

CGUS	Purpose	Technologies
CO_2 Geological Utilization 地质利用	**Energy Production** 能源增采	**Enhanced Oil Recovery, CO_2-EOR** 驱油
		Enhanced Coal Bed Methane, CO_2-ECBM 驱煤层气
		Enhanced Gas Recovery, CO_2-EGR 驱天然气
		Enhanced Shale Gas Recovery, CO_2-ESGR 驱页岩气
	Resources production 其它资源利用	**Enhanced Geothermal Systems, CO_2-EGS** 驱热
		Enhanced Uranium Leaching，CO_2-EUL 驱铀
		Enhanced Water Recovery，CO_2-EWR 驱水
CO_2 Geological Storage 地质封存	**Saline Aquifers, Depleted Oil & Gas Fields, Unmineable Coal Seams** 咸水层，枯竭油气田，不可采煤层	

ACCA21, 2014

3.2 Potential evaluation of CGUS

- **Mesoscale for target selection次盆地尺度（中尺度）**
  - Suitable for potential assessment of one basin or the inner regional areas, similar as regional scale.
  - Between basin and site scales which needs more geological survey for CCUS demonstration or industrialization in the short term, generally before 2030 according to carbon reduction target of China.
  - Because of the large coverage and complicated geology different from abroad, the methodologies and parameters should be more suitable for geology.
  - Without considering the technical and economic conditions.

Innovation of methodology 方法创新

USDOE Methodology

$$G_{CO2} = A \cdot h \cdot \varphi_e \cdot \rho_{CO2} \cdot E$$

- Focus on comprehensive geological study
  更注重系统的地质分析
- Specified the evaluated units as sandstone groups or sections,
  评估单元细化至段，甚至砂层组
- Defined the same parameters in the similar sedimentary faces
  以岩相为单元取参
- Fully integrated with USDOE methodology and GIS spatial analysis
  充分发挥了USDOE计算方法和GIS空间数据分析优势

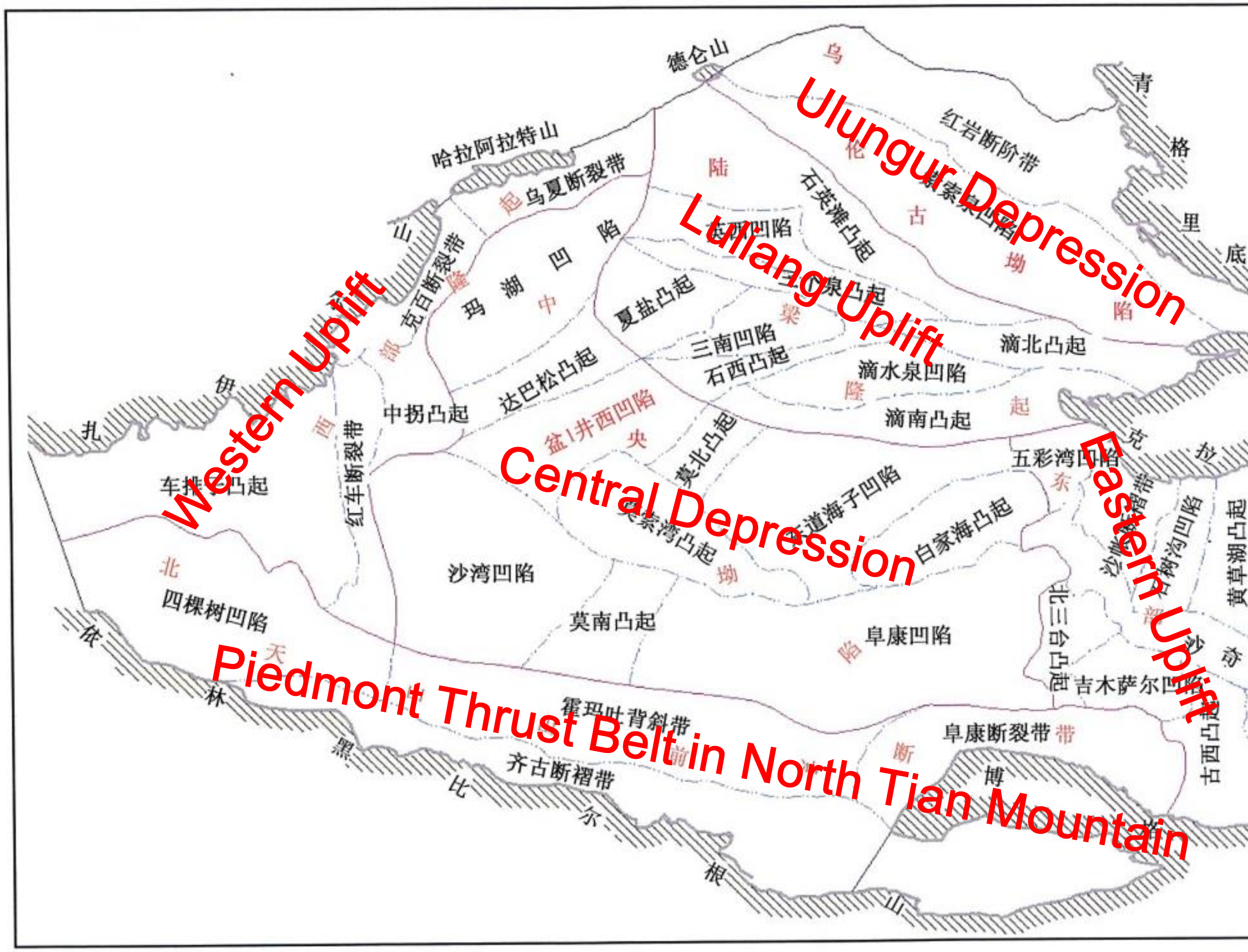
3.2 Potential evaluation of CGUS

- Area: 135,000 km^2
- Length: 700 km
- Width: 340 km

3.2 Potential evaluation of CGUS

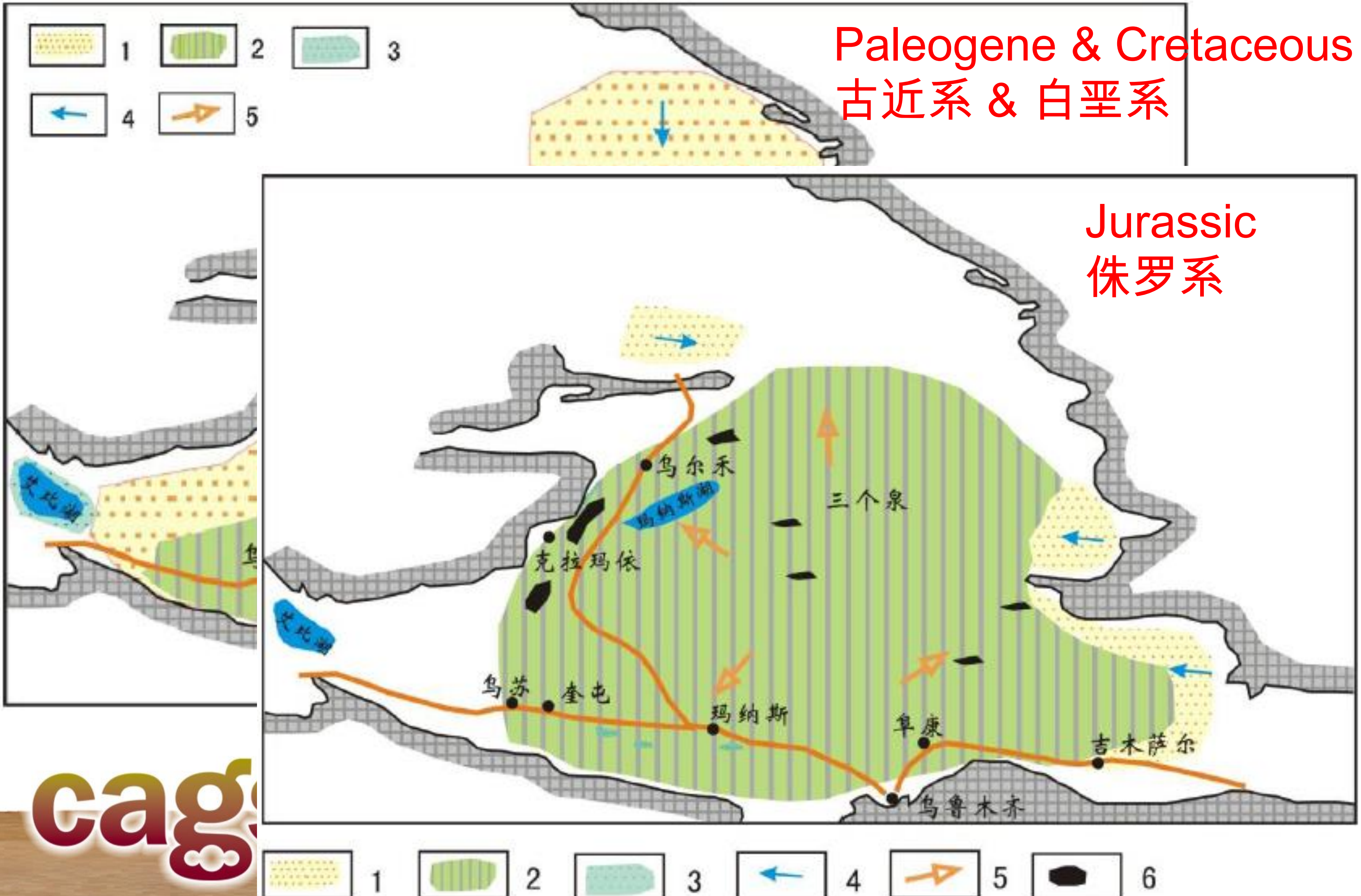
First order tectonic units 一级构造单元: 6

Secondary tectonic units 二级构造单元: 44

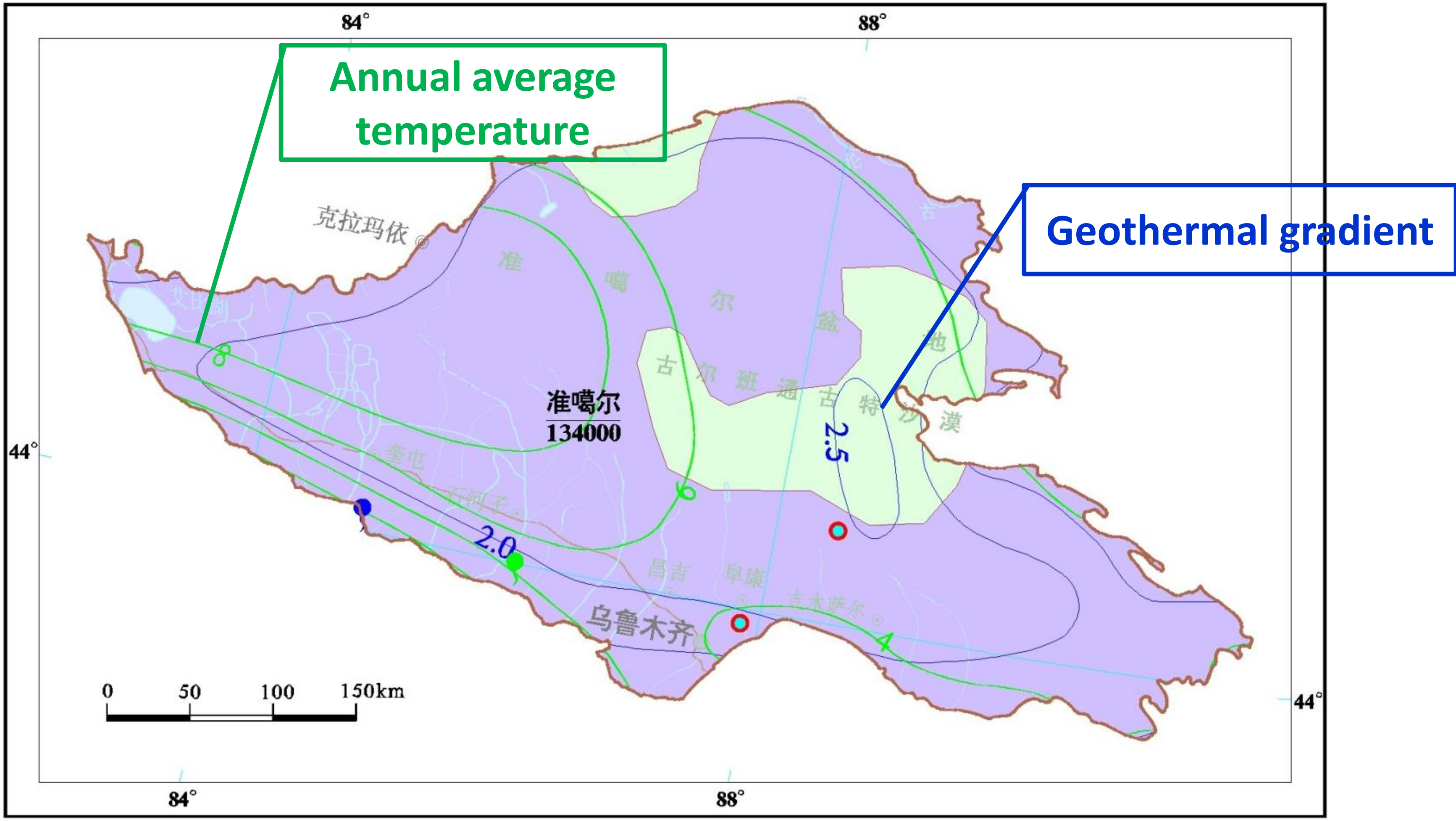


系	组	地层代号	厚度(m)	岩性剖面
Q	西域组	Q_1x	2478	
N	独山子组	N_2d	2800	
	塔西河组	N_1t		
	沙湾组	N_1s		
E	安集海河组	E_3a	1180	
	紫泥泉子组	$E_{1\text{-}2}z$		
K	东沟组	K_2d	2000	
	连木沁组	K_1l		
	胜金口组	K_1s		
	呼图壁河组	K_1h		
	清水河组	K_1q		
J	齐古组	J_3q	3600	
	头屯河组	J_2t		
	西山窑组	J_2x		
	三工河组	J_1s		
	八道湾组	J_1b		
T	白碱滩组	T_3b	1700	
	克拉玛依组	T_2k		
	百口泉组	T_1b		

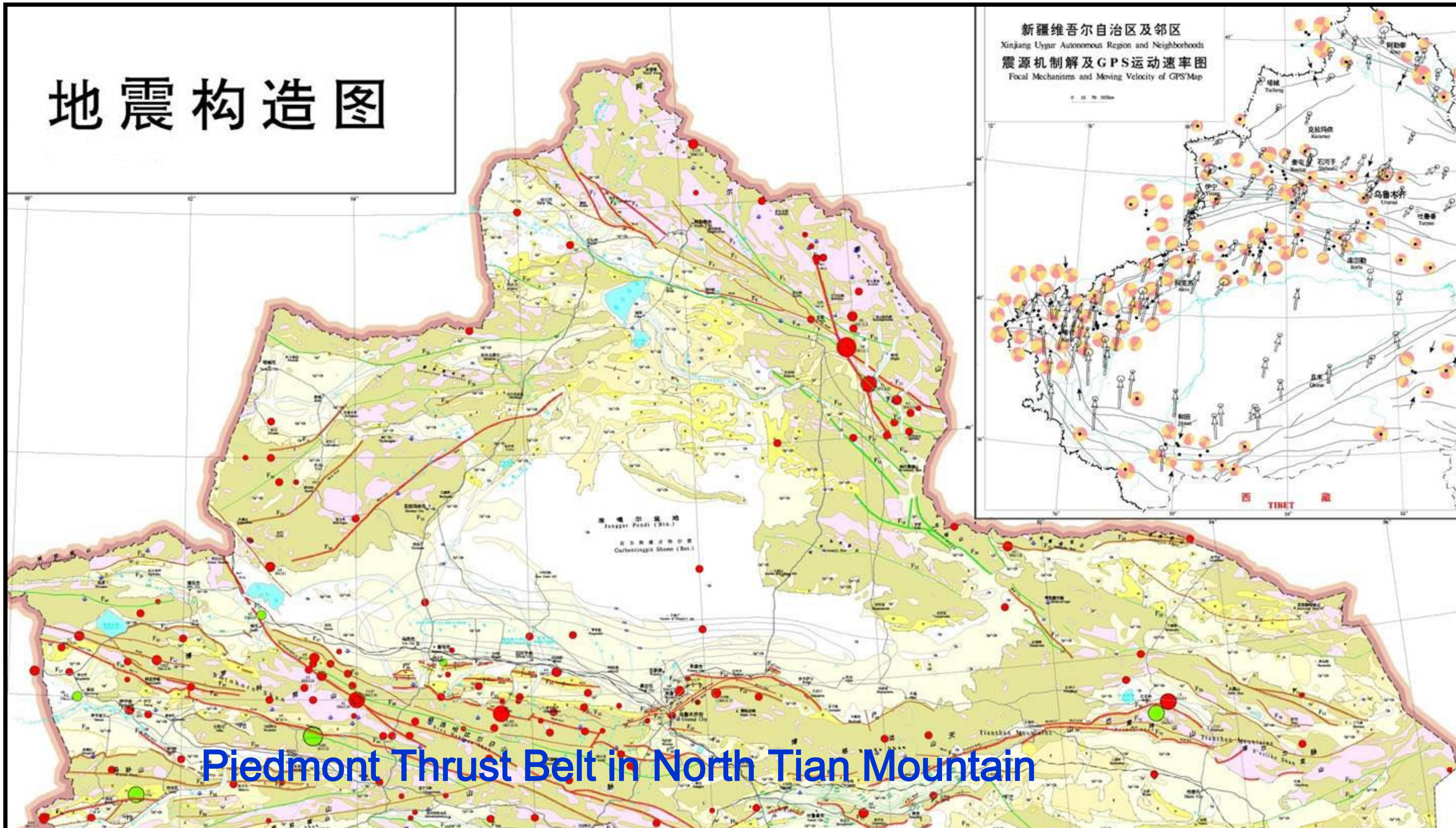
Hydrogeology 区域水文地质



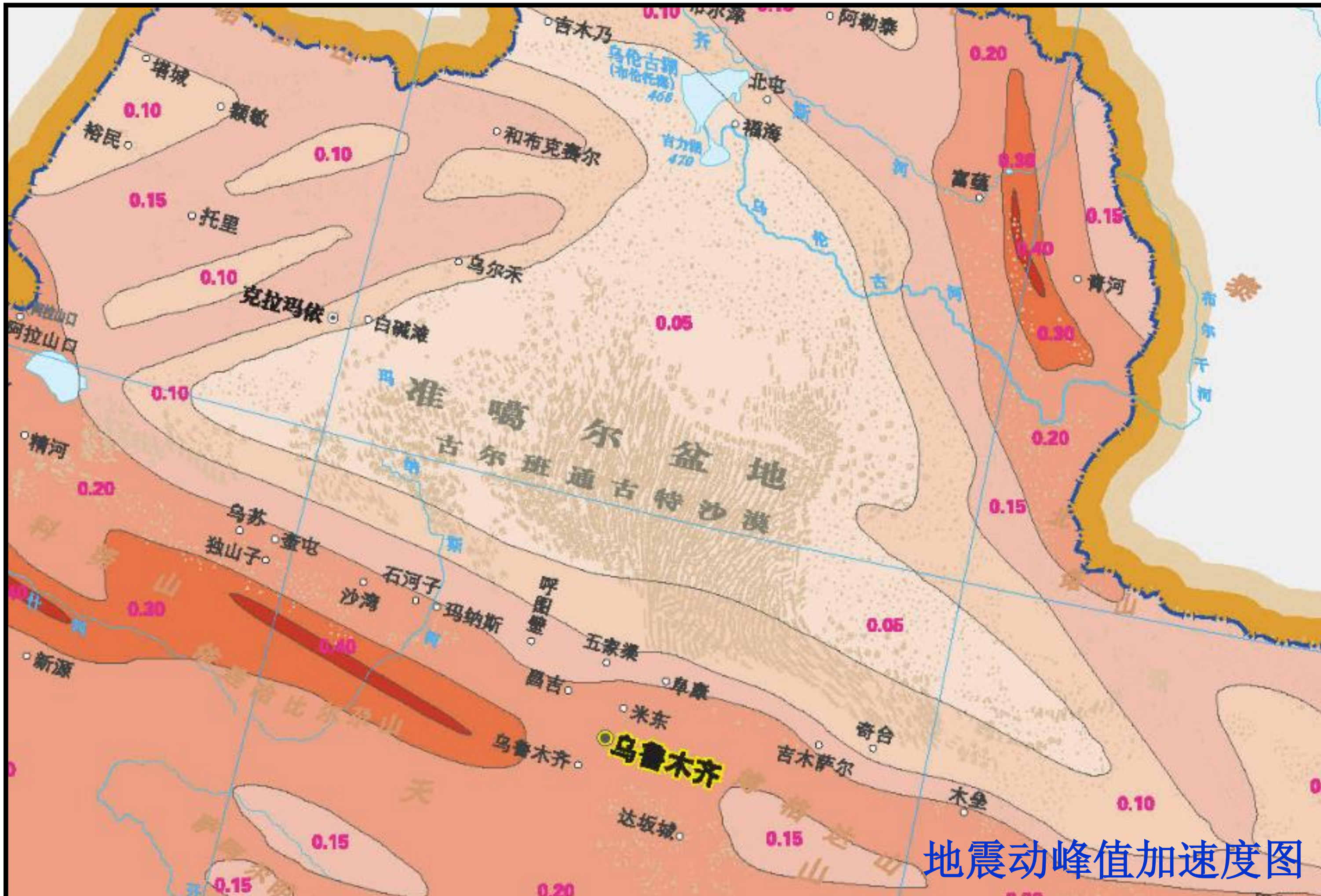
Geothermal geology 区域地温场



Seismotectonics 地震构造



Peak ground acceleration (GB 18306-2015)



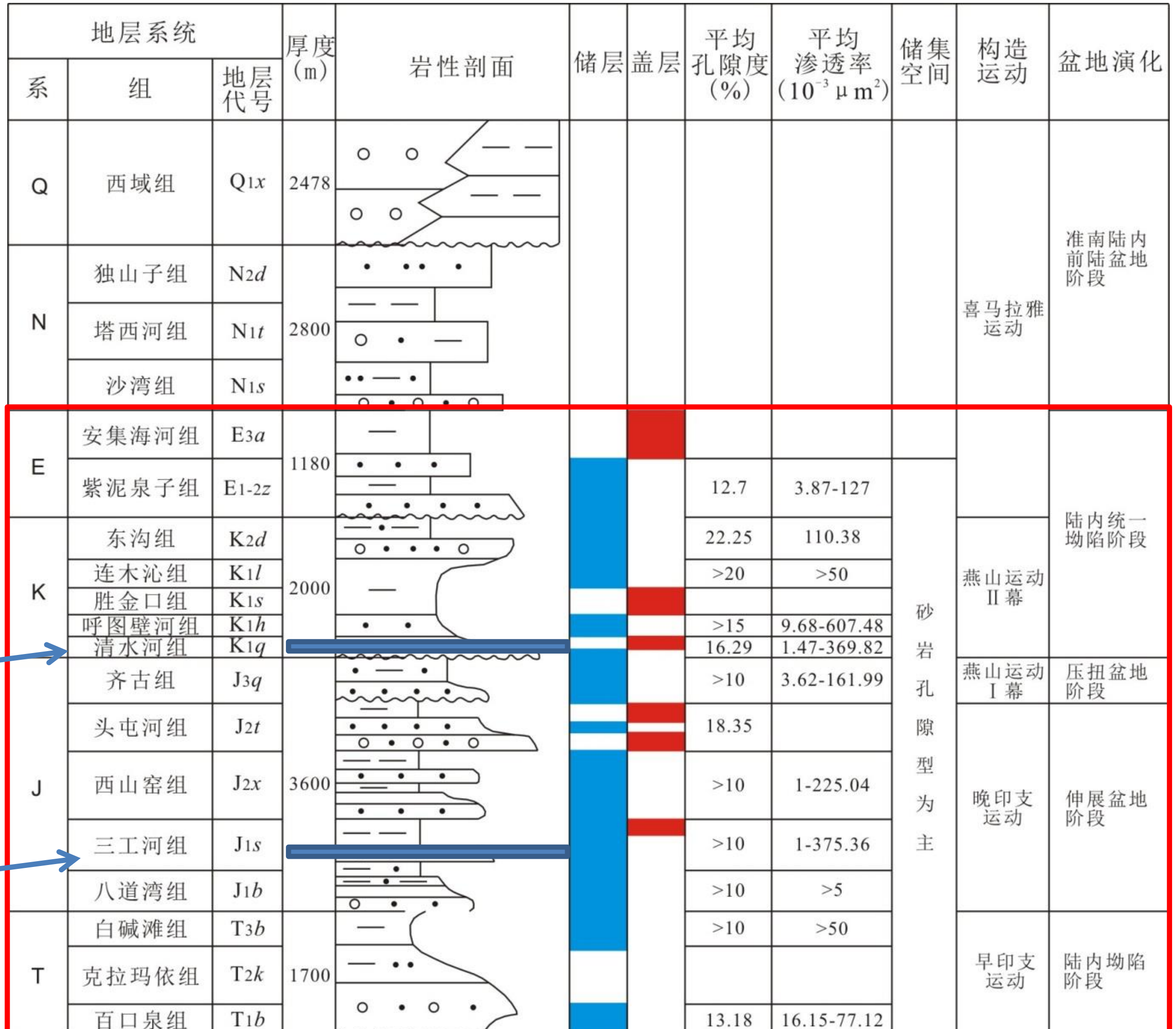
3.2 Potential evaluation of CGUS

Criteria for reservoir selection basically:
储层的必须满足的基本条件：

- 深度 Depth: 800 – 3500 m
- 岩性 Lithology: clastic rocks, carbonate rocks
- 厚度 Thickness: ≥ 10 m
- 孔隙度 Porosity: ≥ 5%
- 渗透率 Permeability: ≥1 mD
- 盖层 Caprocks: regional, generally mudstone and thicker than 20 m
- 活动断裂 Distance from the nearby active faults: > 25 km
- 地震活动性 Peak ground acceleration: < 0.40 g
- 水动力条件 Hydrogeology: not open hydrodynamic area

3.2 Potential evaluation of CGUS

23 reservoirs



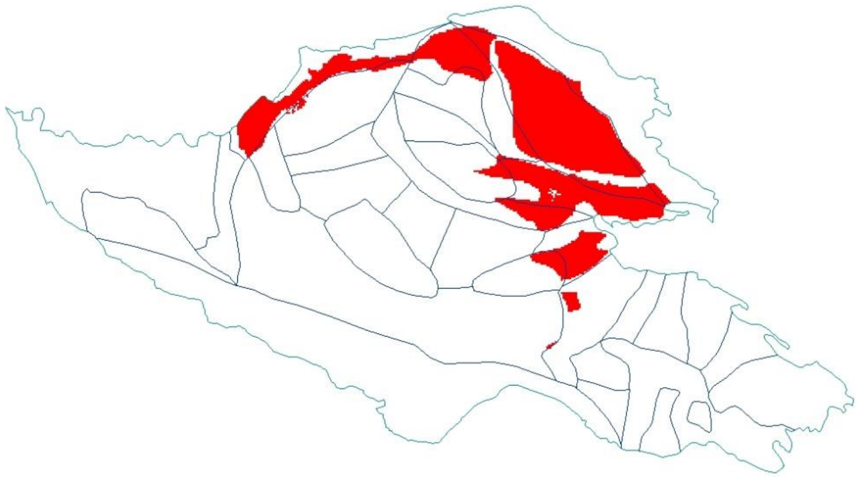
Section2 of Sangonghe formation

Sand-ravel rock in the bottom of Qingshuihe formation

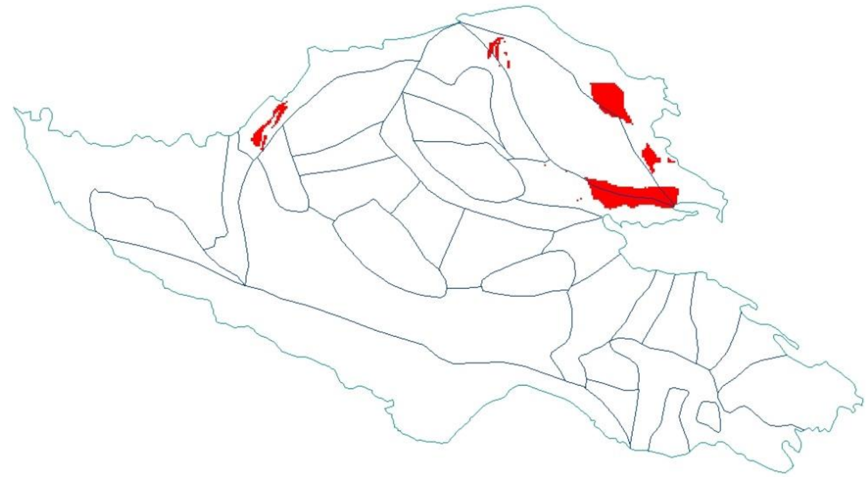
3.2 Potential evaluation of CGUS

- Triassic reservoirs
  三叠系储层

Low exploration and research degree



Baikouquan Formation
Φ: 13.18% average
K:16.55 - 77.12 mD

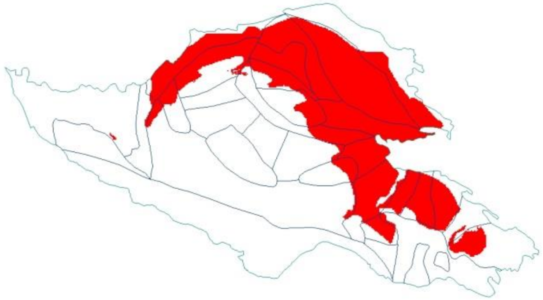


Baijiantan Formation
Φ: 14.1% - 19.12%
K: 20.92 ~ 57.48 mD

3.2 Potential evaluation of CGUS

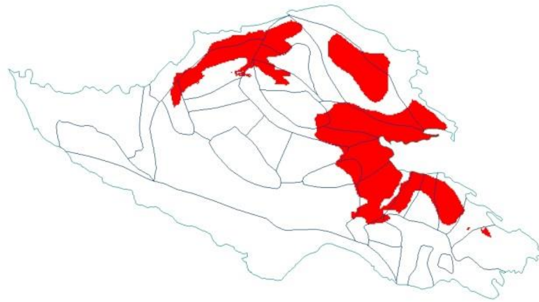
– Jurassic reservoirs 侏罗系储层

Badaowan Formation



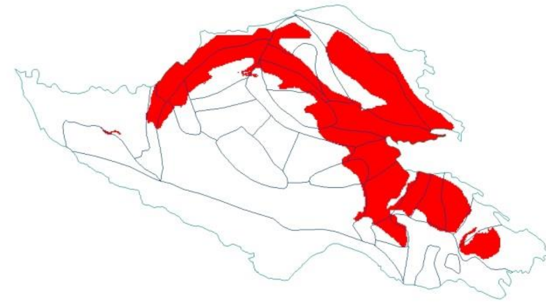
Section1

Φ: 8.61% average
K: 2.31 mD average



Section2

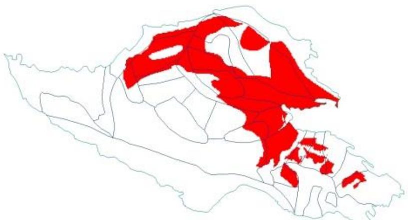
Φ: 15.29% average
K: > 10 mD



Section3

Φ: 16.14% average
K: > 10 mD

Sangonghe Formation



Section1

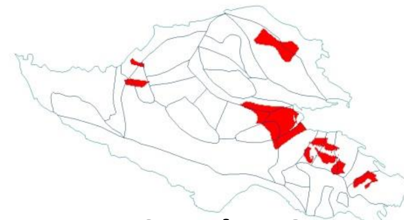
Φ: 9.64% average
K: 30.18-375.36 mD

Section2-2

Φ: 12.74% average
K: 1-190 mD

Section2-1

Φ: 11.38% average
K: 1-143 mD



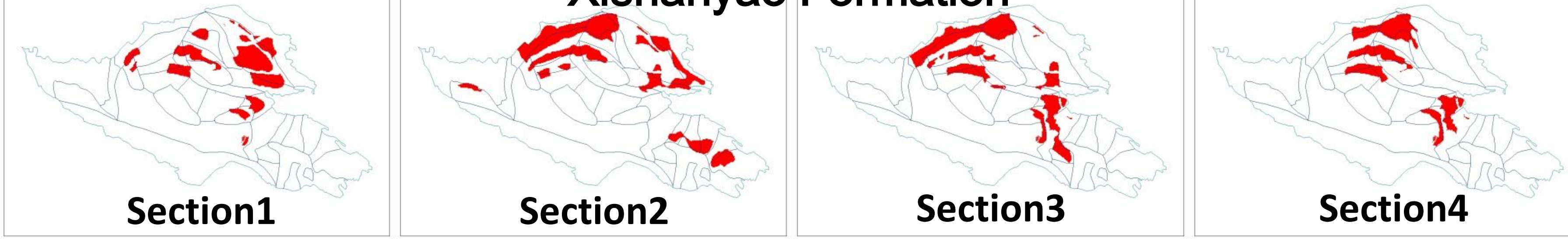
Section3

Φ: 16.54% average
K: 17.58-75.76 mD

3.2 Potential evaluation of CGUS

– Jurassic reservoirs 侏罗系储层

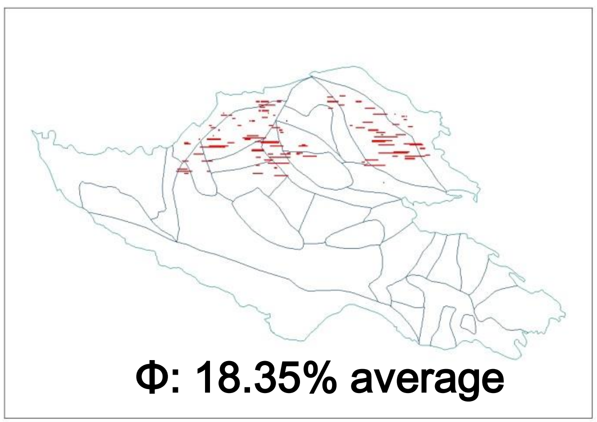
Xishanyao Formation



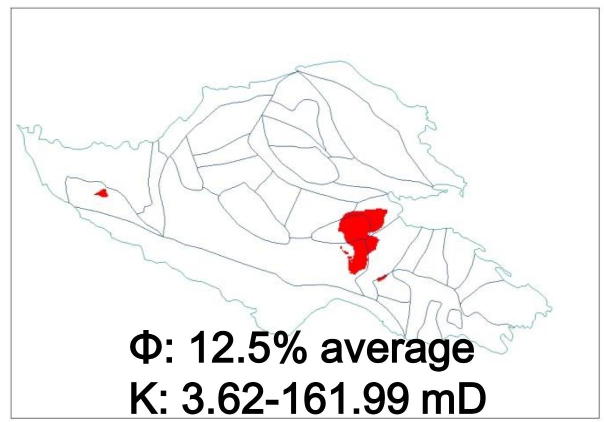
Φ: 13.1-19.7%
K: 2.7-225 mD

Φ: 19.7% average
K: 225 mD average

Φ: 13.1-19.7%
K: 2.7-225 mD



Toutunhe Formation

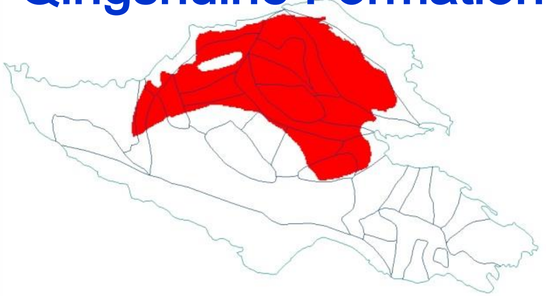


Qigu Formation

3.2 Potential evaluation of CGUS

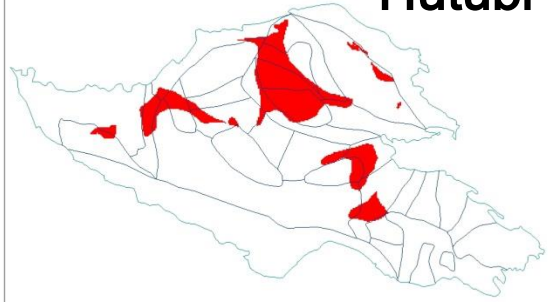
– Cretaceous reservoirs 白垩系储层

Qingshuihe Formation

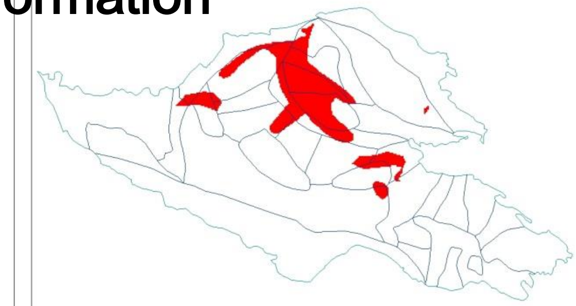


Φ: 16.29% average
K: 1.47-369.82 mD

Hutubi Formation



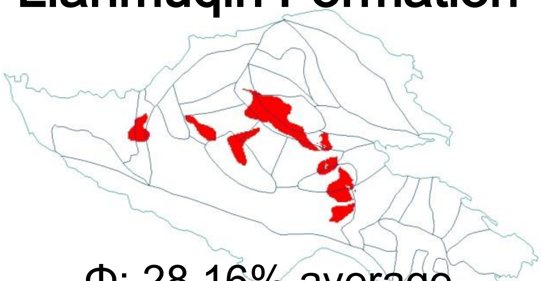
Section1



Section2

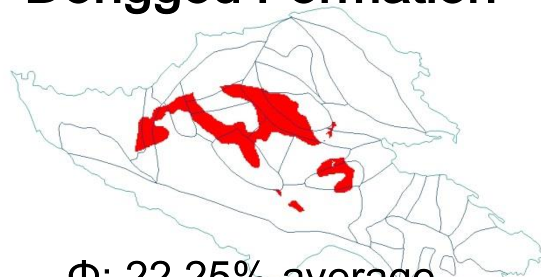
Φ: 18.27% average
K: 44.71 mD average

Lianmuqin Formation



Φ: 28.16% average
K: 166.22 -529.84 mD

Donggou Formation

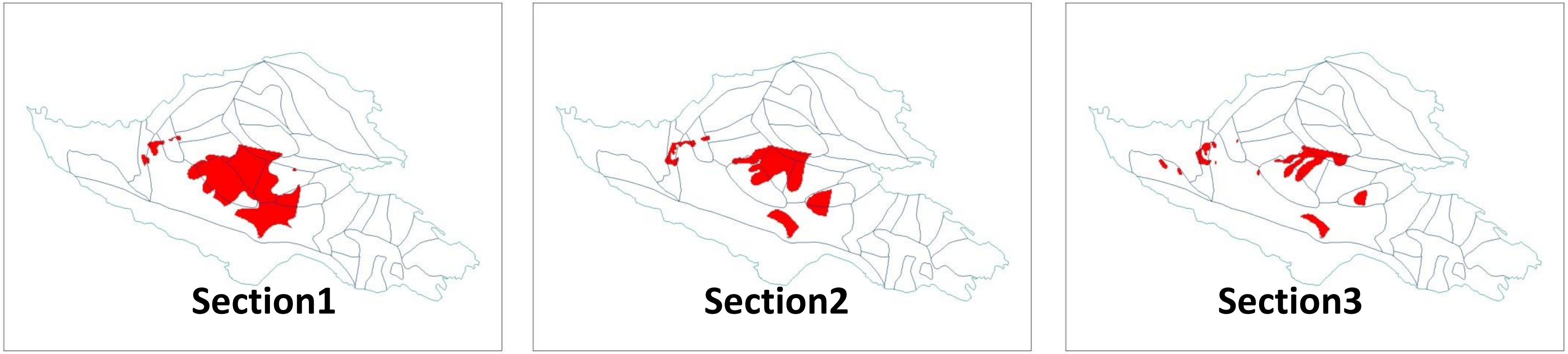


Φ: 22.25% average
K: 110.38 mD average

3.2 Potential evaluation of CGUS

- Paleogene reservoirs
  古近系储层

Ziniquanzi Formation



Φ: 12.47% average
K: 3.87-127 mD

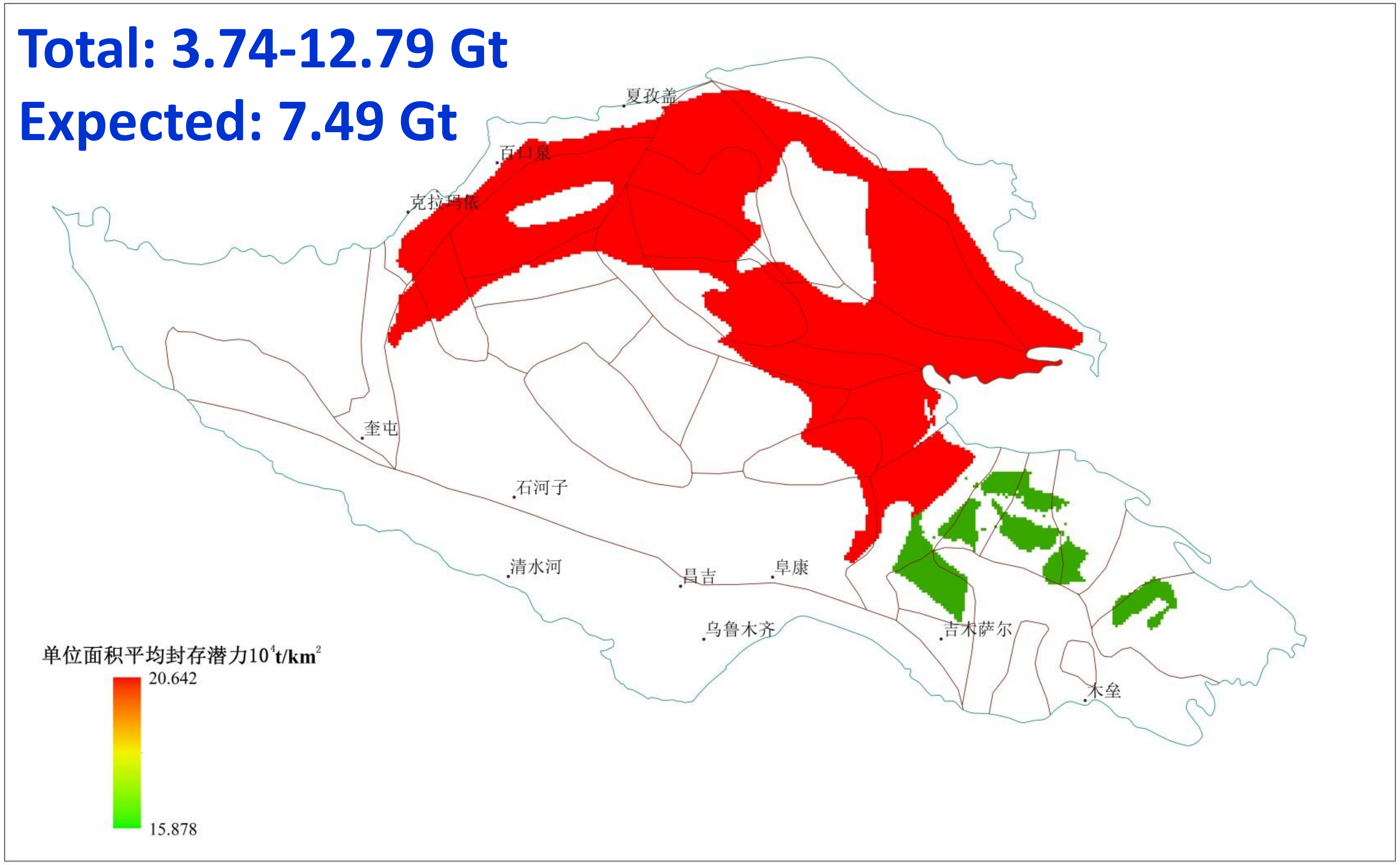
3.2 Potential evaluation of CGUS

CGUS technologies	Potential (Gt)	Credibility
Enhanced oil recovery, CO_2-EOR	0.148	Effective, Credible
Depleted oil field CO_2 storage	1.345	Effective, Credible
Enhanced gas recovery, CO_2-EGR	0.009	Effective, Credible
Depleted gas field CO_2 storage	0.016	Effective, Credible
Enhanced coal bed methane, CO_2-ECBM	2.281-5.215 4.02 expected	Theoretical, Less Credible
Unmineable coal seams CO_2 storage	3.405-7.783 6 expected	Theoretical, Less Credible
CO2-EWR/deep saline aquifers	4.8027-164.093 96.055 expected	Theoretical, Less Credible

3.2 Potential evaluation of CGUS

Total: 3.74-12.79 Gt

Expected: 7.49 Gt



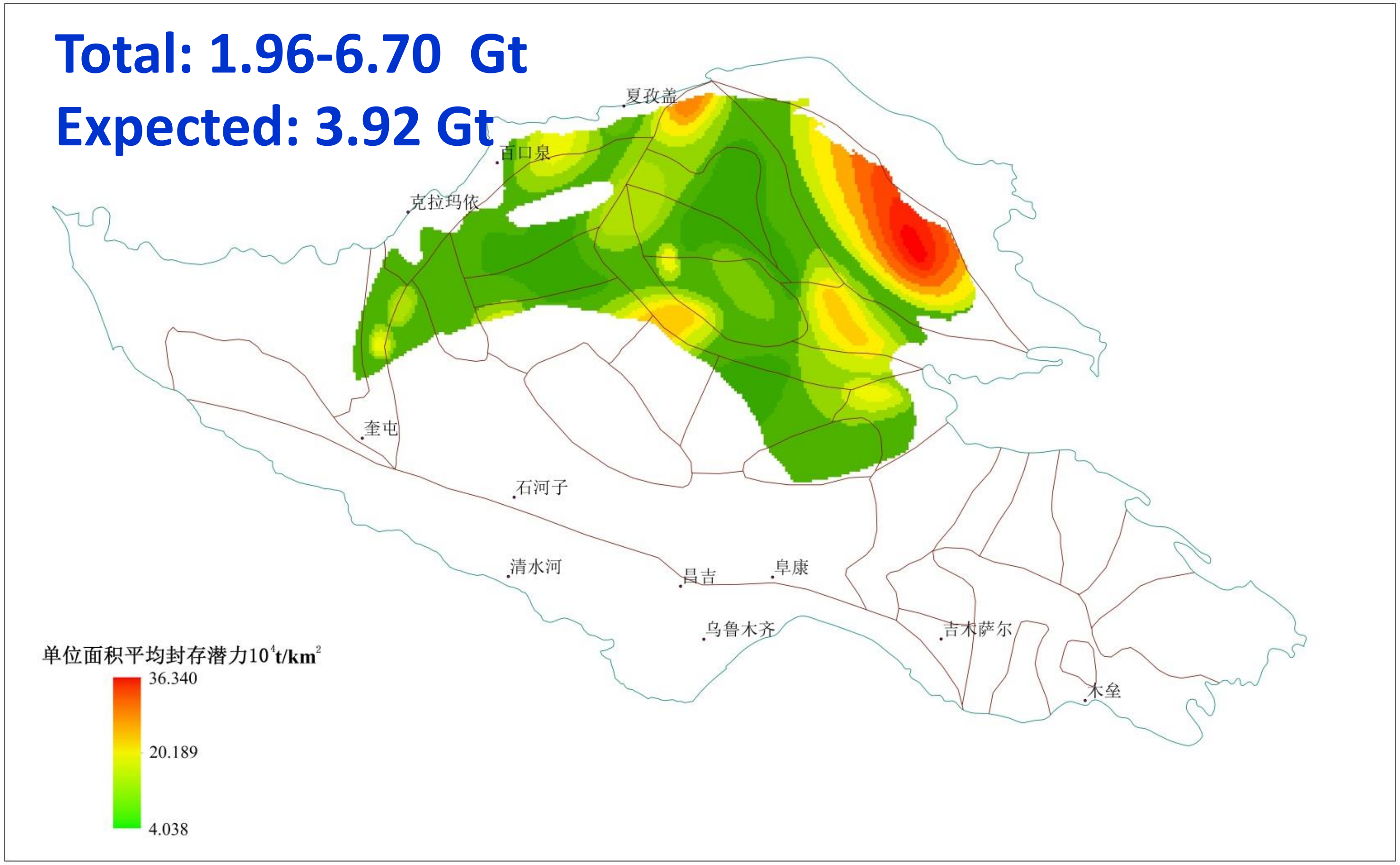
Potential of 2nd sandstone group in section 2 of Sangonghe Formation

三工河二段二砂组主力储层单位面积封存潜力

3.2 Potential evaluation of CGUS

Total: 1.96-6.70 Gt

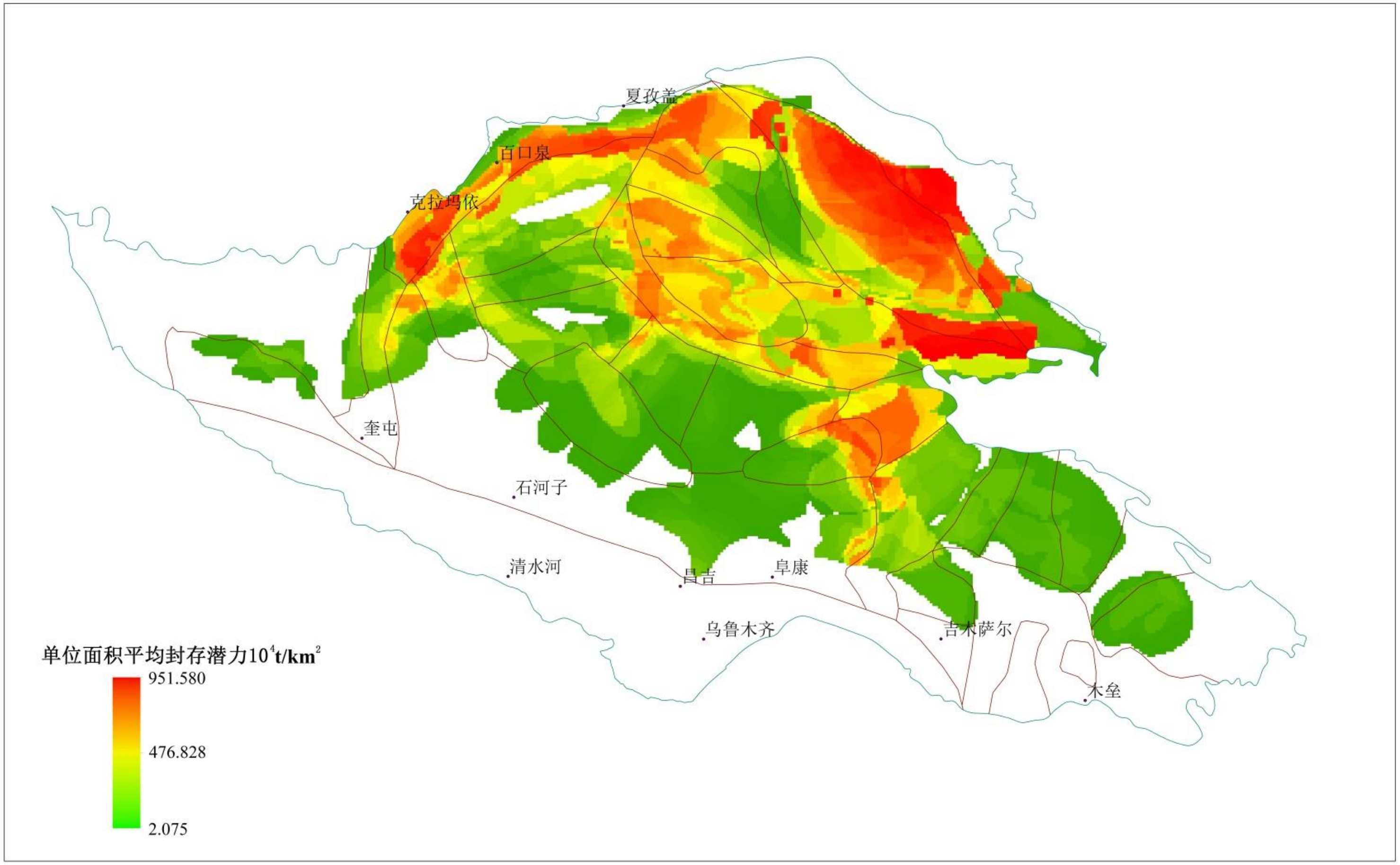
Expected: 3.92 Gt



Potential of sandstones in the bottom of Qingshuihe Formation

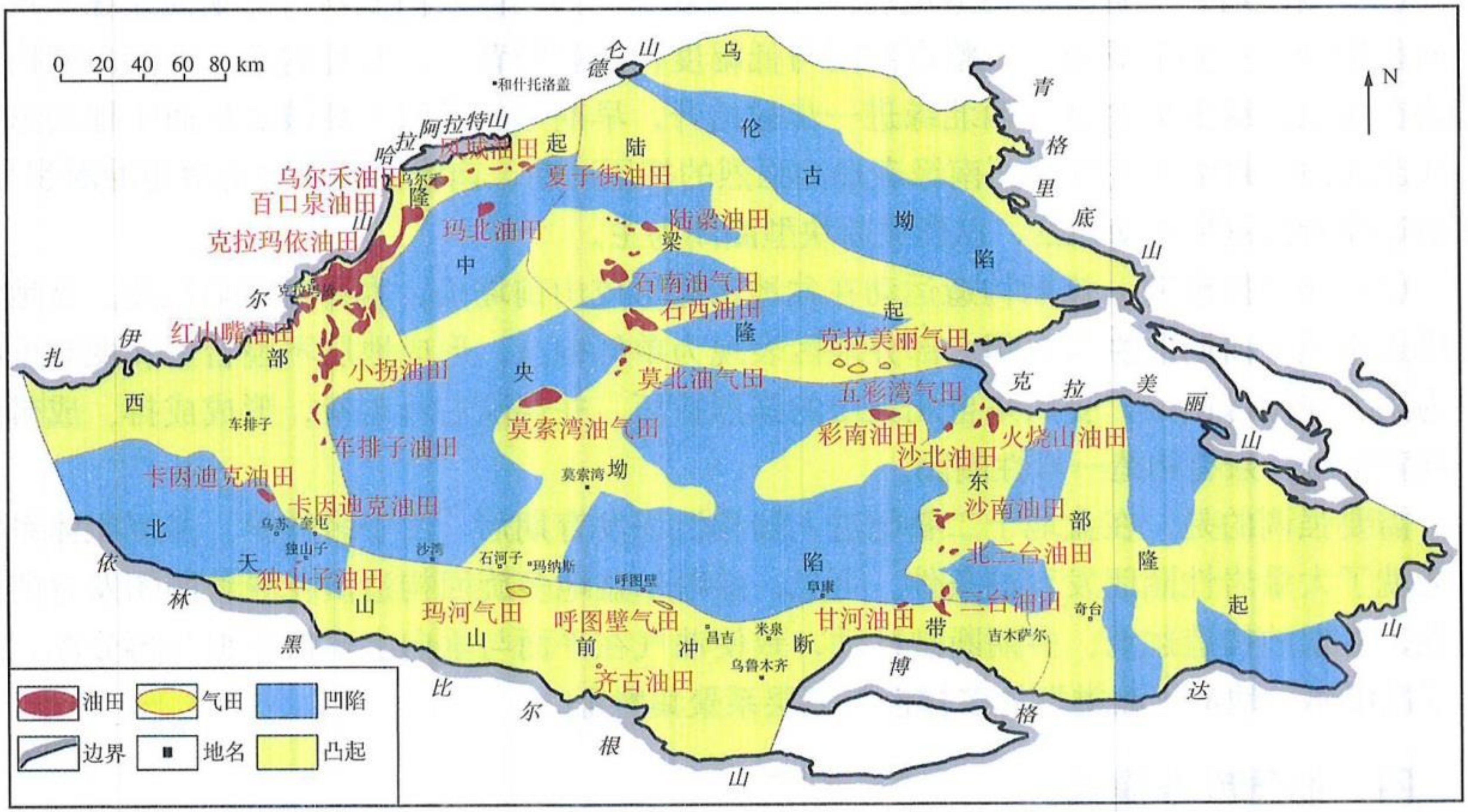
清水河组底部砂砾岩主力储层单位面积封存潜力

3.2 Potential evaluation of CGUS



Total potential of deep saline aquifers CO2 geological storage/EWR

3.3 Targets of EOR/EGR/depleted oil & gas fields CO2 storage

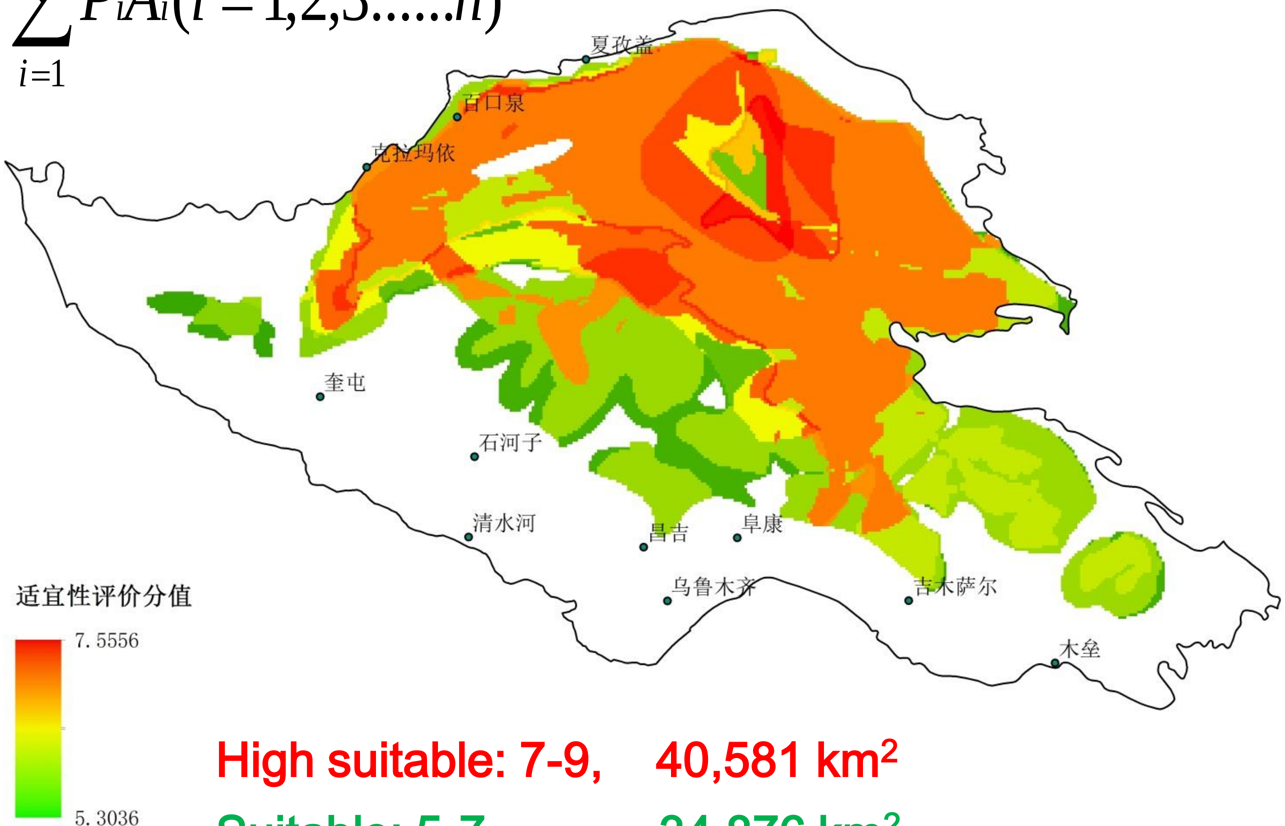


3.4 Geological suitability assessment for CO2-EWR target selection

Level one index	Weight	Level two index	Weight	Level three index	Weight	Good	Normal	Poor	Key veto factor
Reservoir conditions and storage potential	0.50	Characteristic of the best reservoir	0.60	Lithology	0.07	Clastic	Mix of Clastic and Carbonate	Carbonate	
				Single layer thickness h/m	0.11	≥80	30 ≤ h < 80	10 ≤ h < 30	< 10
				Sedimentary facies	0.36	River, Delta	Turbidity, Alluvial fan	Beach bar, Reef	
				Average porosity ϕ/%	0.20	≥15	10 ≤ ϕ < 15	5 ≤ ϕ < 10	< 5
				Average permeability k/ mD	0.27	≥50	10 ≤ k < 50	1 ≤ k < 10	< 1
		Storage potential	0.40	Storage potential per unit area G (10^4 t/km^2)	1.00	≥100	10 ≤ G < 100	< 10	
Geological safety	0.50	Characteristic of the main caprock	0.62	Lithology	0.30	Evaporites	Argillite	Shale and dense limestone	
				Thickness h/m	0.53	≥100	50 ≤ h < 100	10 ≤ h < 50	< 10
				Depth D/m	0.11	<1000	1000 ≤ D ≤ 2700	>2700	
				Buffer caprock above the main caprock	0.06	Multiple sets	Single set	None	
		Hydrodynamic conditions	0.24	Hydrodynamic conditions	1.00	Groundwater high-containment area	Groundwater containment area	Groundwater semi-containment area	Groundwater open area
		Seismic activity	0.14	Peak ground acceleration	0.50	< 0.05 g	0.05 g, 0.10 g	0.15 g, 0.30 g	≥0.40 g
				Development degree of fractures	0.50	Simple	Moderate	Complex	Within 25 km of active faults

3.4 Geological suitability assessment for CO2-EWR target selection

$$P = \sum_{i=1}^{n} P_i A_i \quad (i = 1, 2, 3 \ldots\ldots n)$$



High suitable: 7-9, 40,581 km^2

Suitable: 5-7, 34,876 km^2

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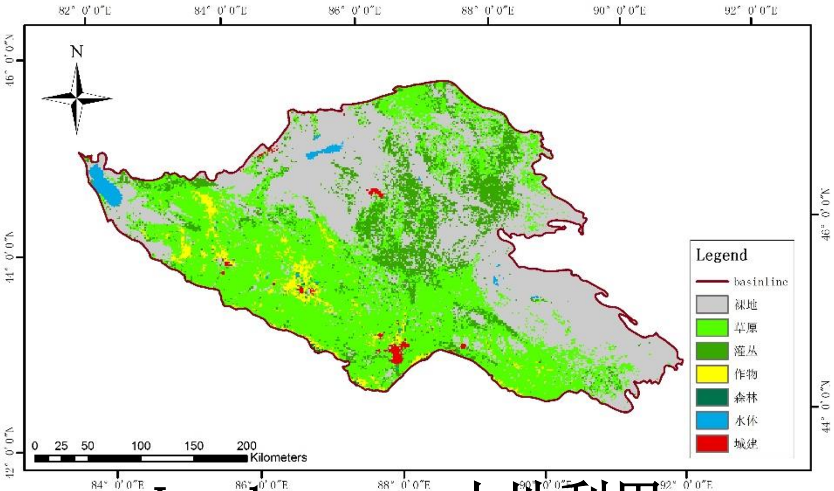
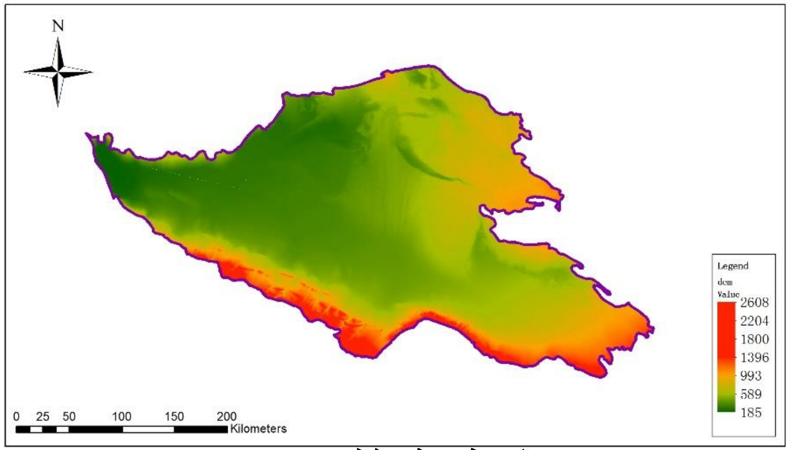
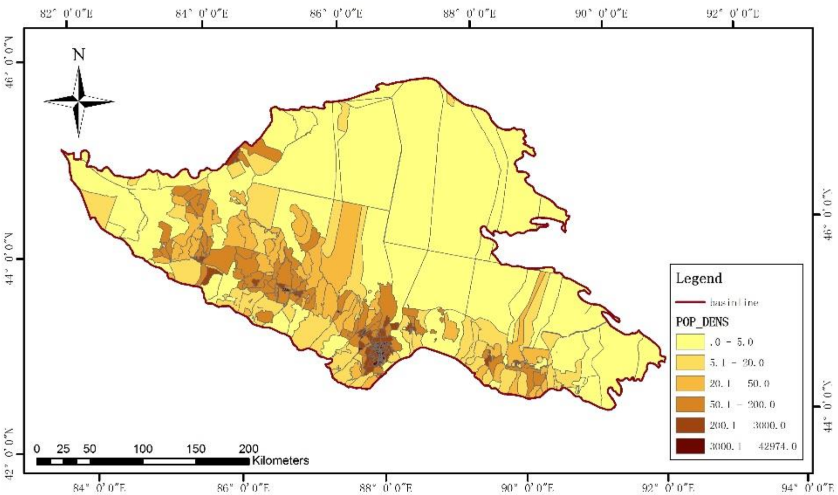
4.1 Geographic information for GIS analysis



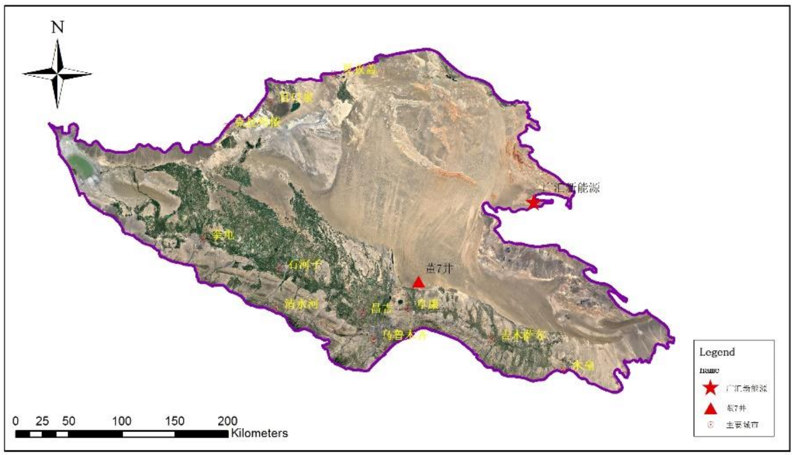
Land cover 土地利用



DEM 数字高程

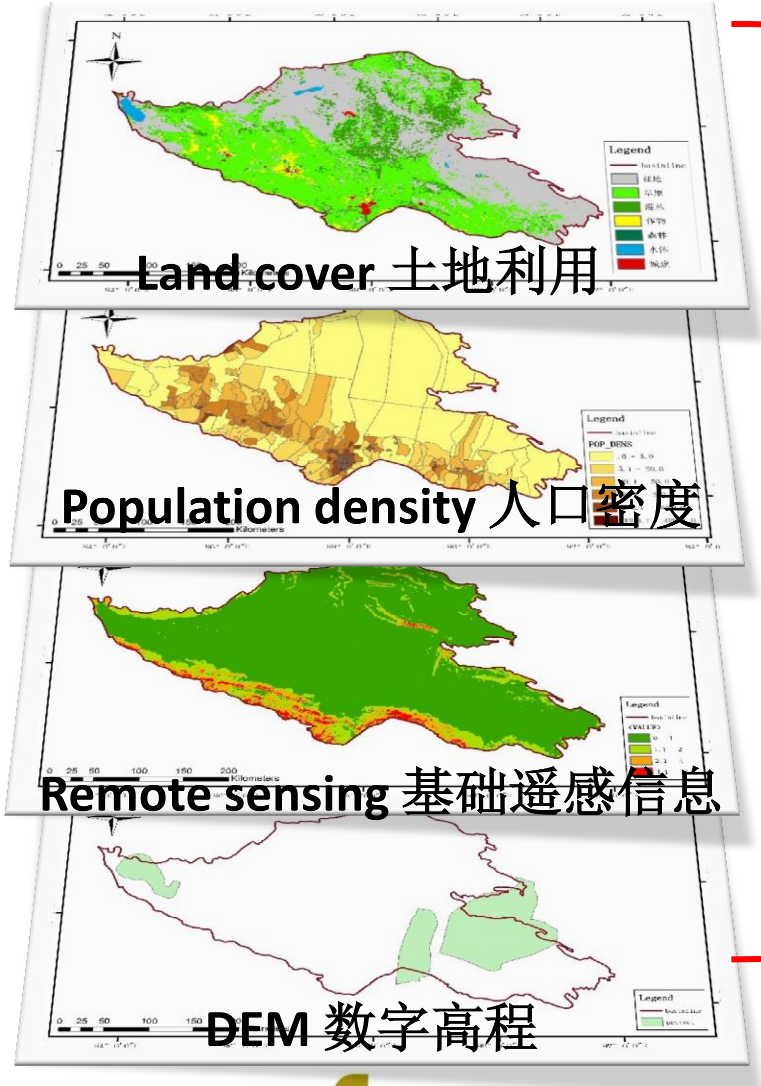


Population density 人口密度

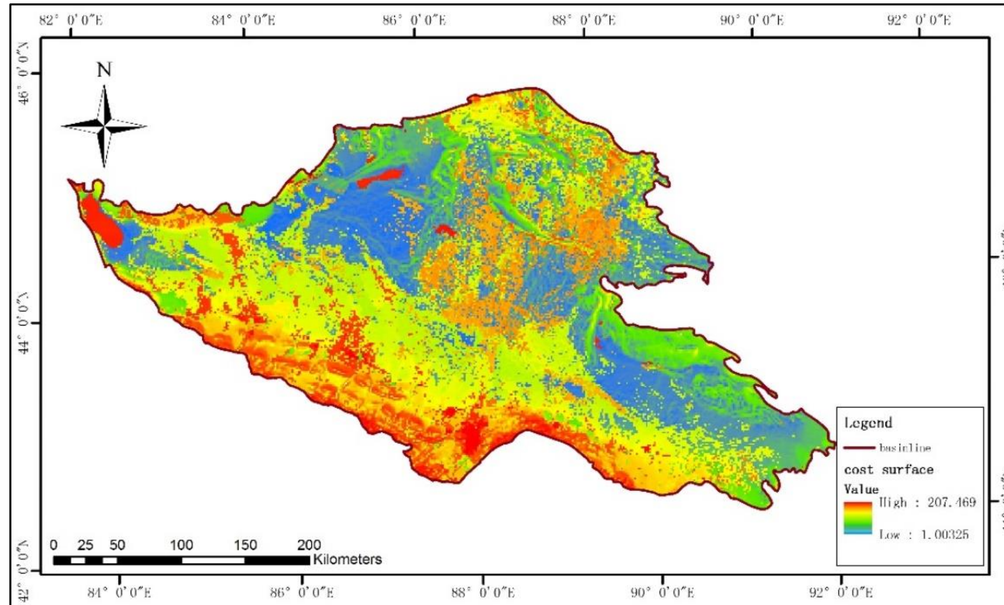


Remote sensing 基础遥感信息

4.2 Cost Surface

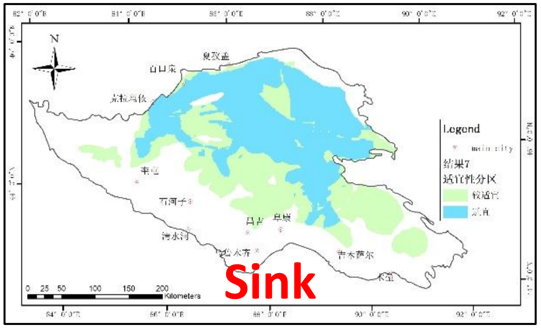


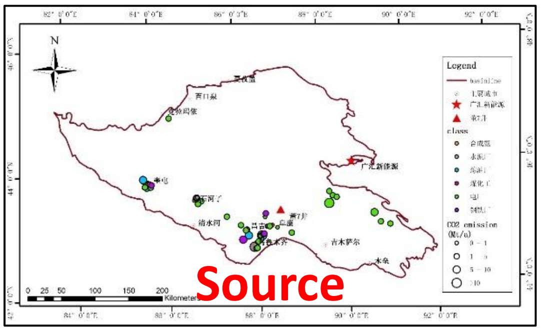
Cost surface

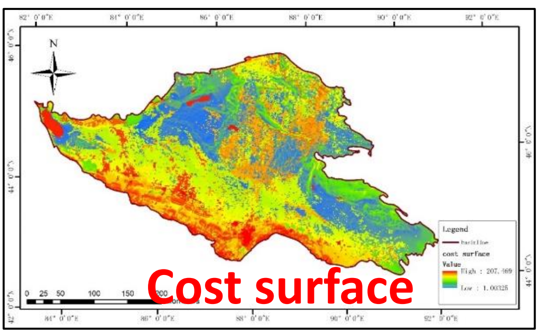


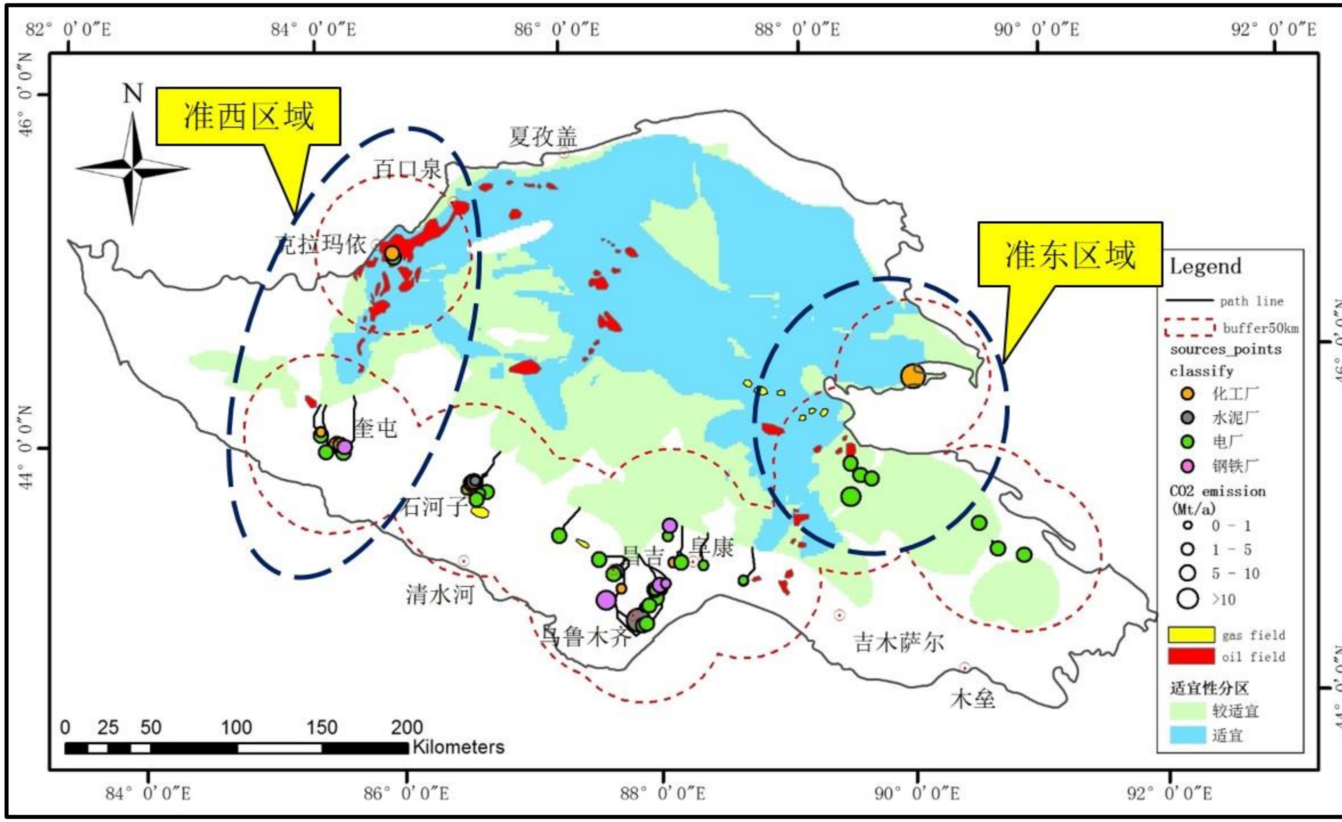
GIS Spatial Analysis

4.3 Source-sink matching of aquifers CO2 storage





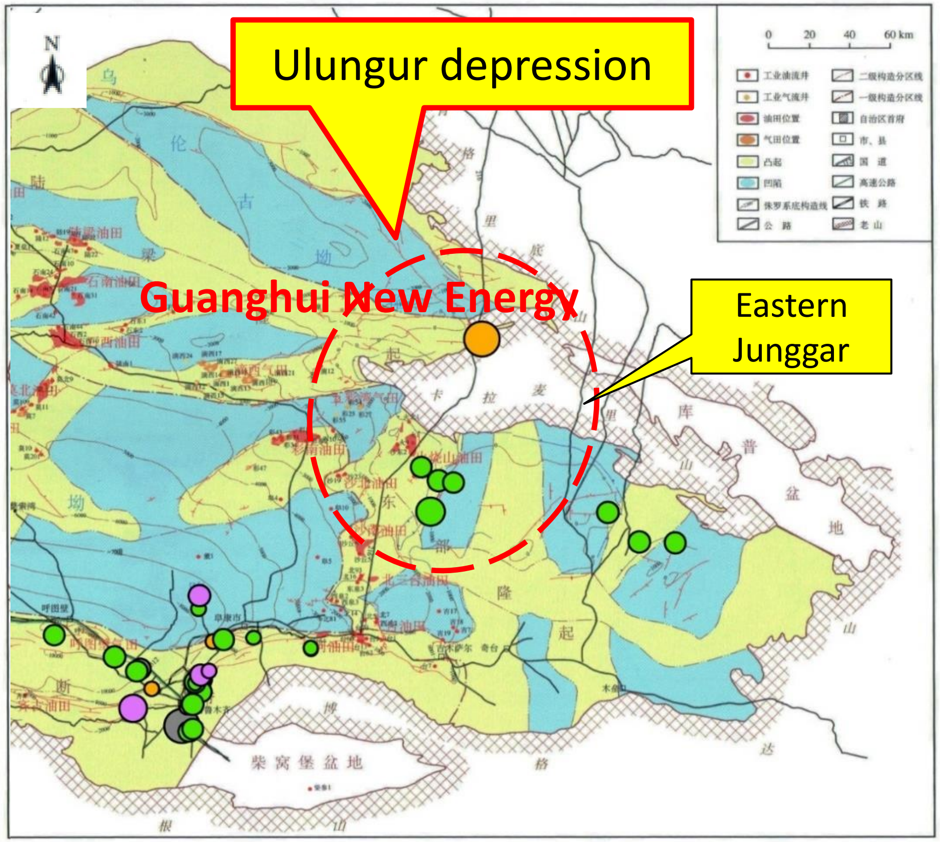




- 源汇匹配条件好；多处场地可就近封存(＜50 km)；
- Conditions of source-sink matching is good for deep saline aquifers or CO2-EWR; Most of CO2 sources can match a suitable storage site nearby (＜50 km).

4.3 Source-sink matching of aquifers CO_2 storage

Eastern Junggar Basin



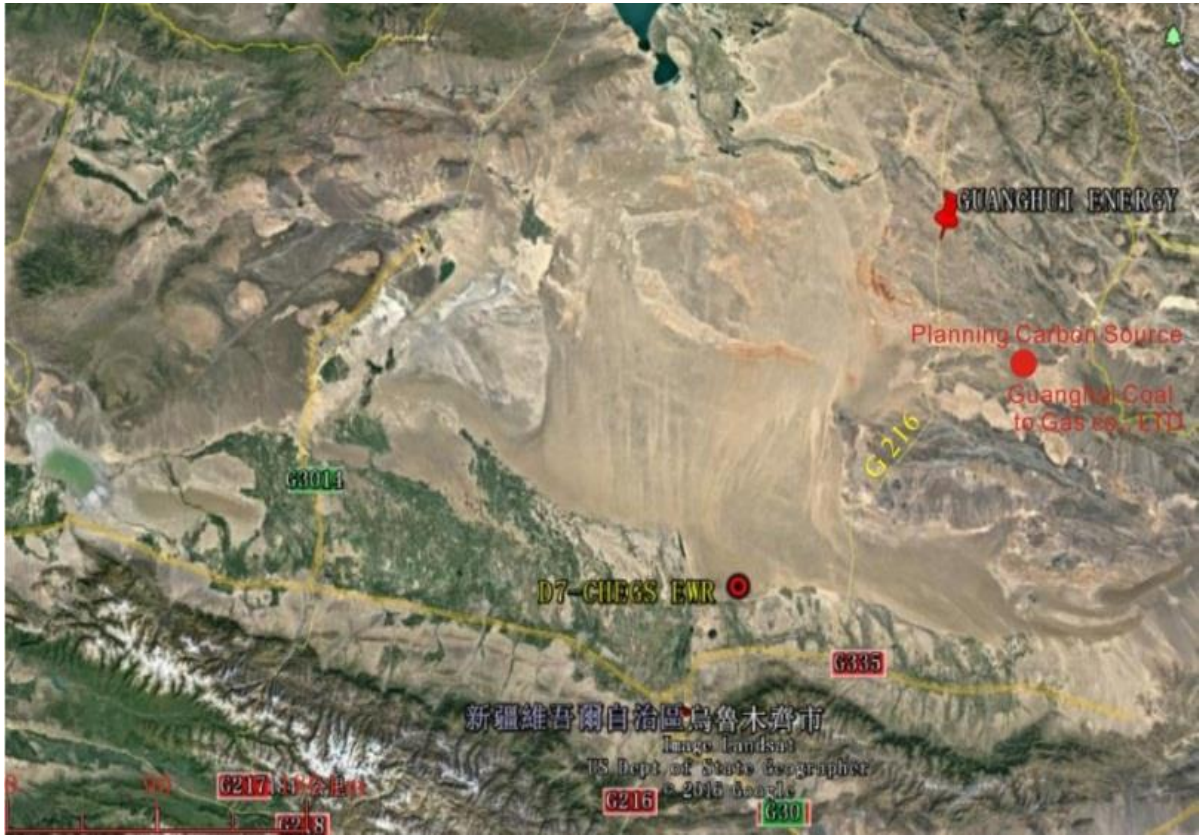
- 准东地区适宜开展CO_2-EWR或咸水层封存示范项目。
  - 排放源主要是电厂和化工厂；电厂正在建设，运营后年排放量约17.61Mt
  - 广汇新能源：西北部的乌伦古坳陷深部咸水层封存潜力巨大，地质条件较好

- Eastern Junggar Basin is suitable for early demonstration of CO_2-EWR or deep saline aquifer CO2 storage.

- Main CO2 sources: mainly are chemistry industries and power plants.
- After completing construction and put into operation, the total emissions is about 17.61Mt/a.
- Guanghui New Energy co., LTD: Ulungur depression located to the northwest of Guanghui, has large aquifer storage capacity and good geological conditions.

CONTENTS

5.1 CO_2 geological storage survey in Eastern Junggar



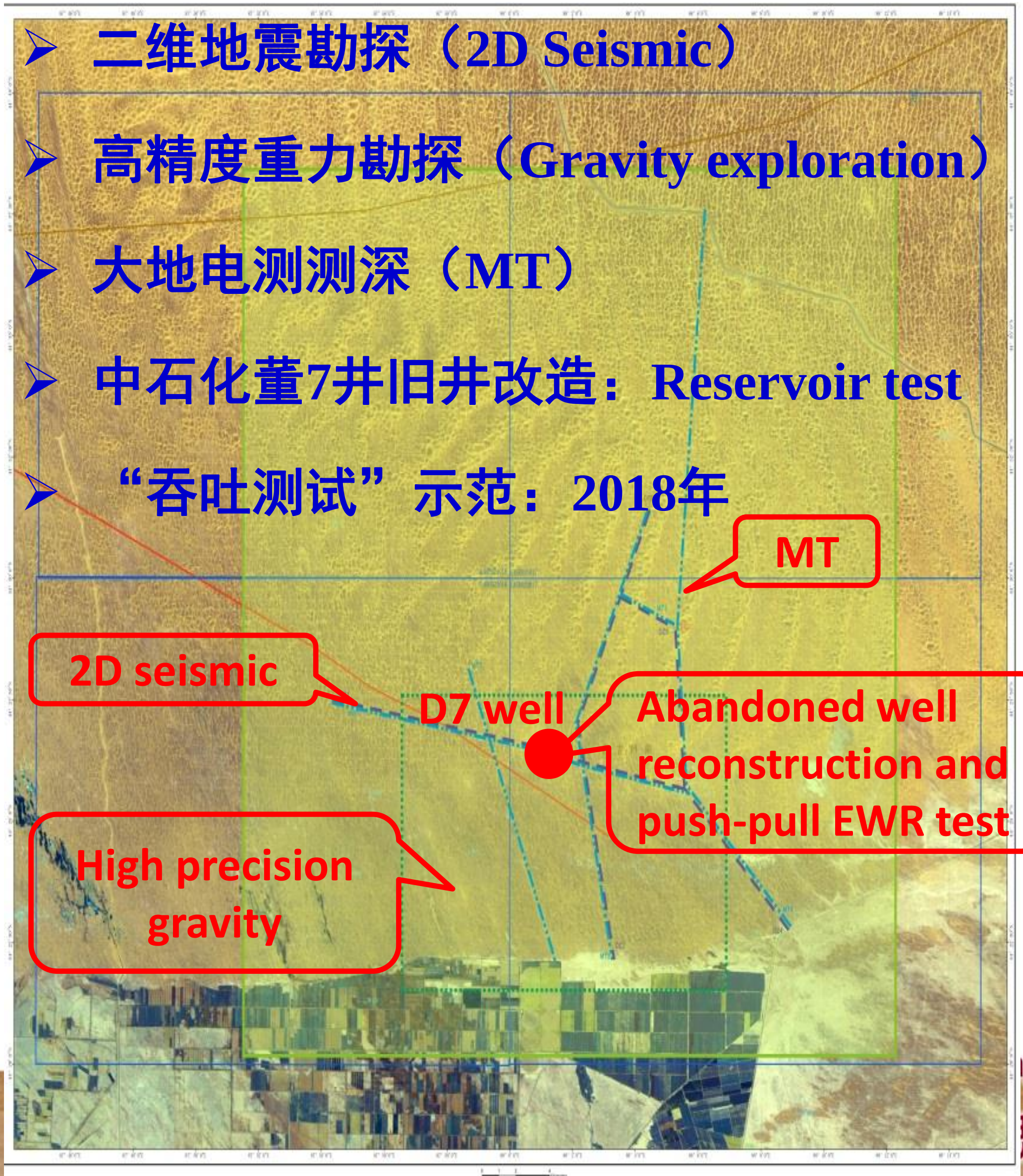
Xinjiang, Junggar Basin

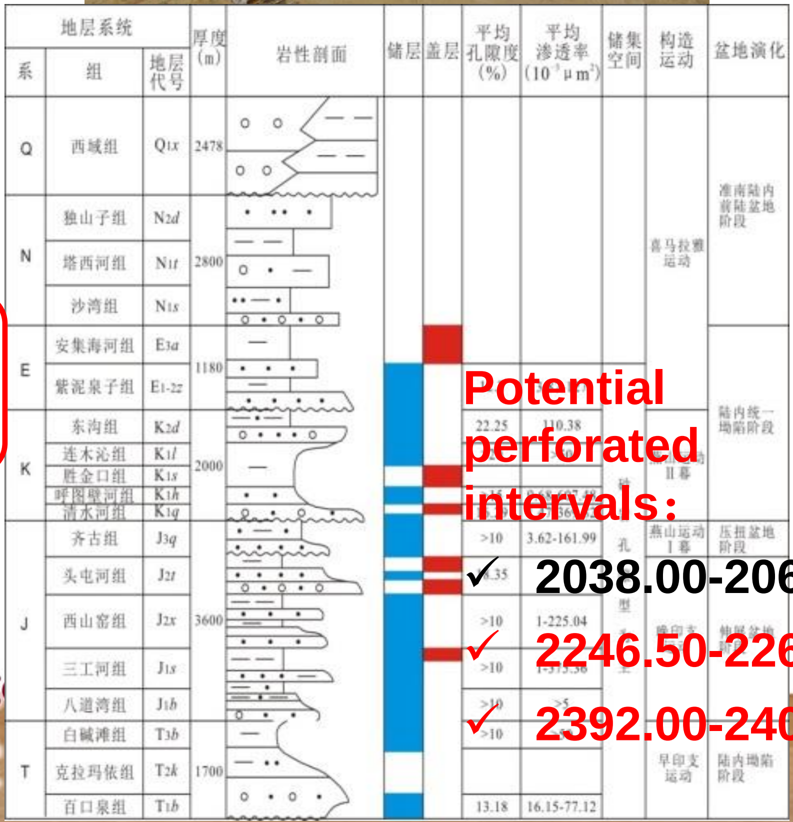
<u>"准噶尔等盆地二氧化碳地质储存综合地质调查"：</u>准东地区阜康北部二氧化碳地质储存碳储工程场地选址调查评价

Geological survey for CO2-EWR in Eastern Junggar Basin, Xinjiang

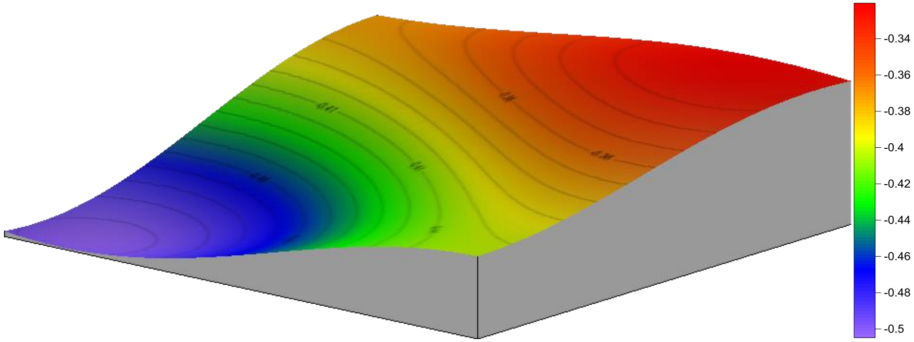
5.2 CGS Pilot project site of CO2-EWR in Eastern Junggar

- 二维地震勘探（2D Seismic）
- 高精度重力勘探（Gravity exploration）
- 大地电测测深（MT）
- 中石化董7井旧井改造：Reservoir test
- “吞吐测试”示范：2018年

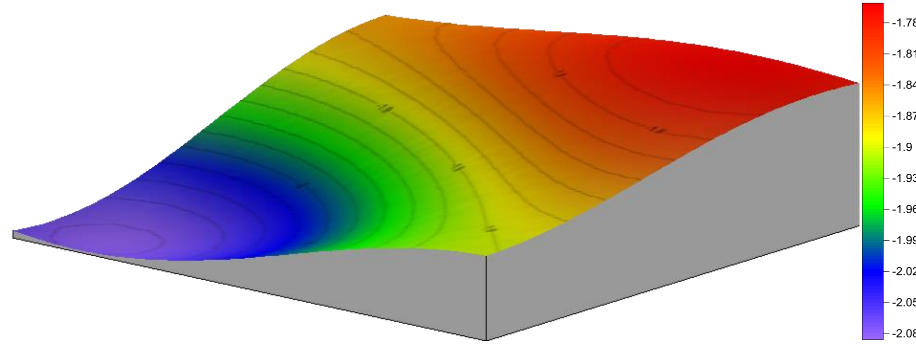




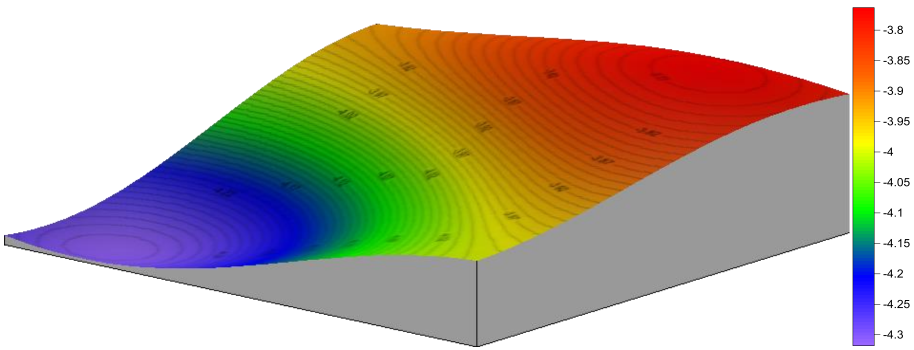
High precision gravity exploration



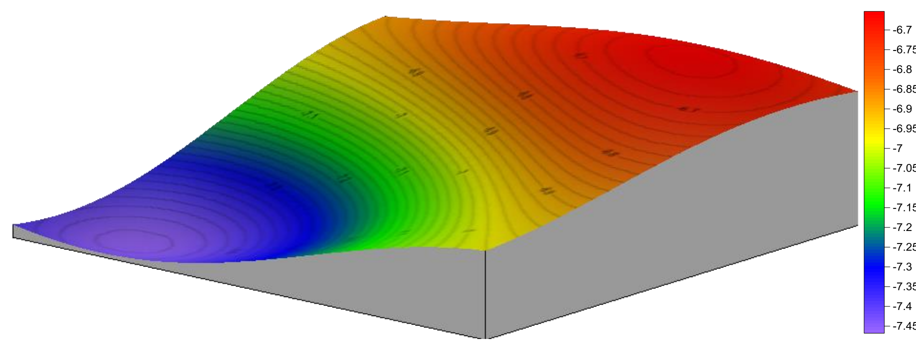
第四系Quaternary
Bottom boundary depth: 320-510 m



第三系Tertiary
Bottom boundary depth: 1760-2100 m

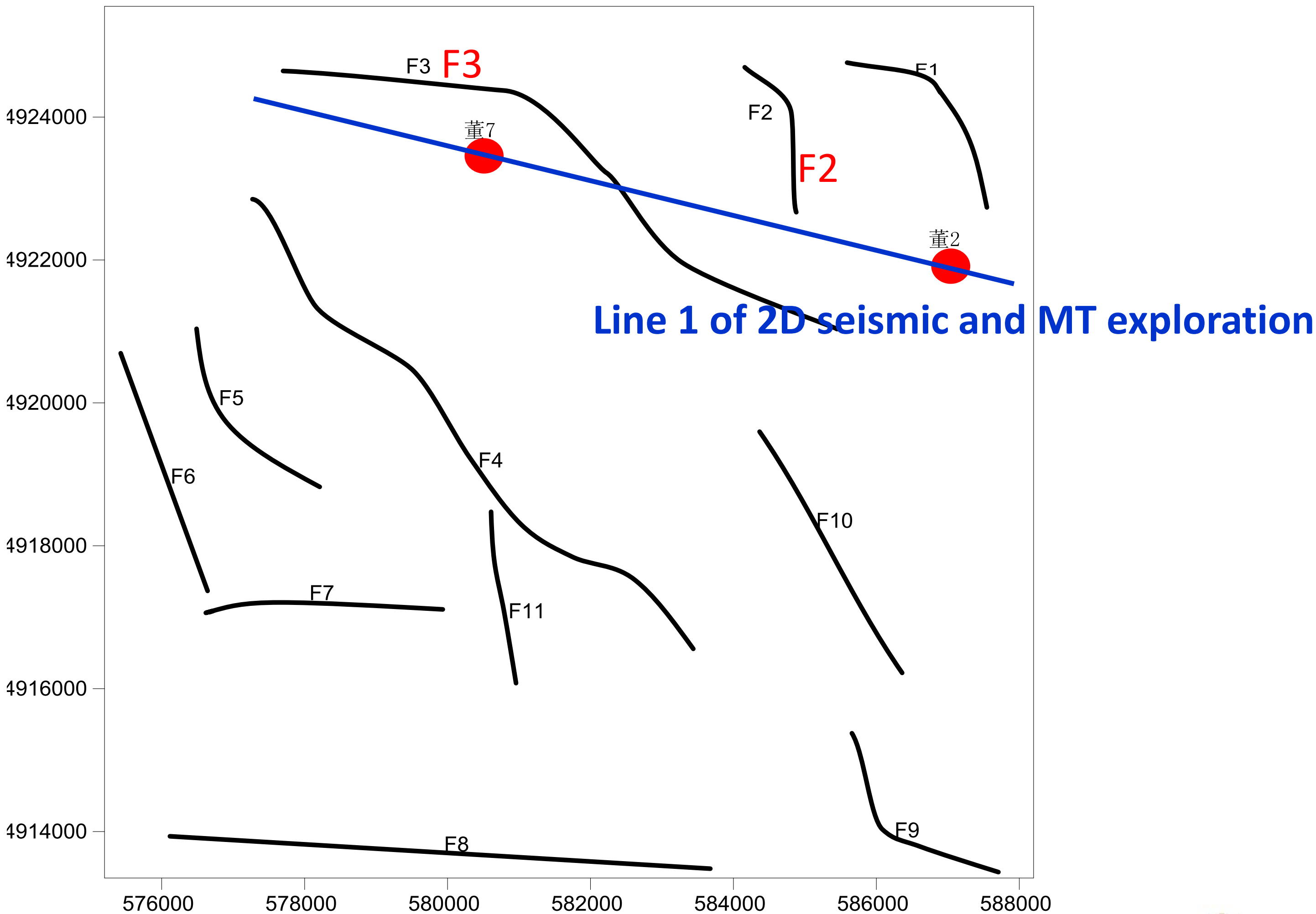


白垩系Cretaceous
Bottom boundary depth: 3760-4320 m

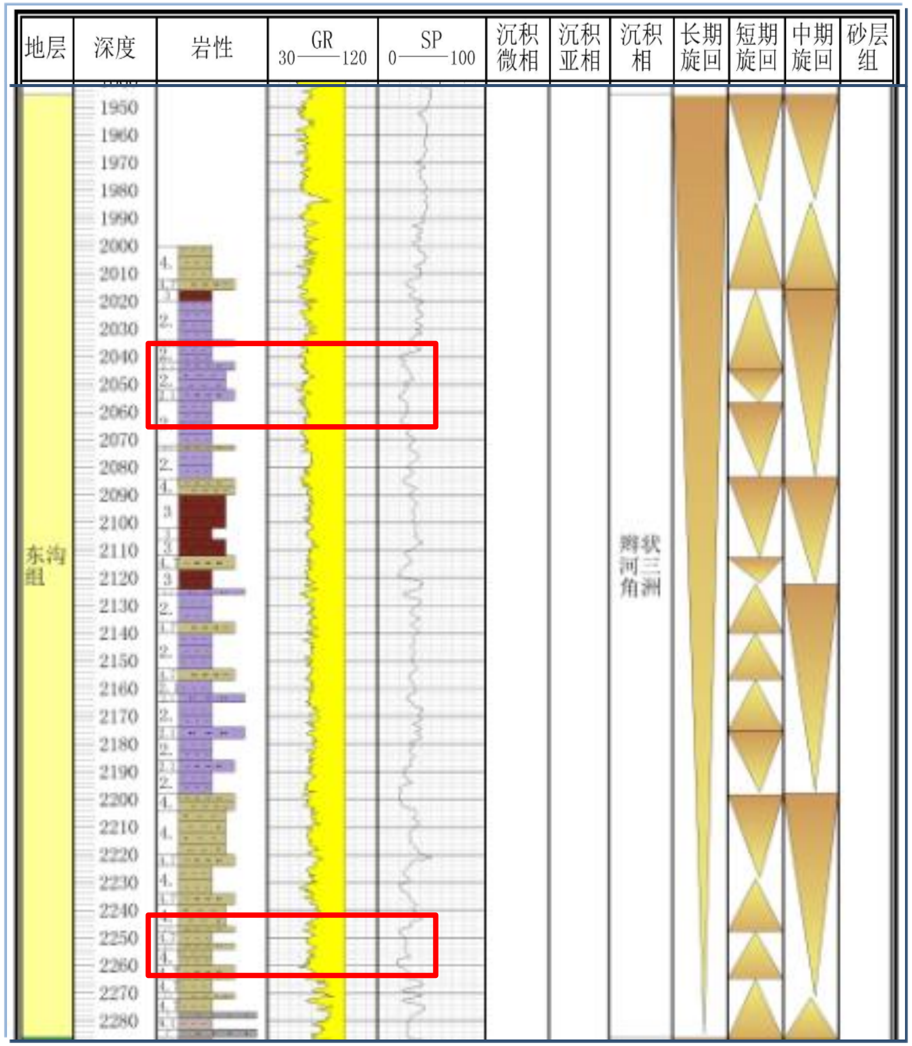


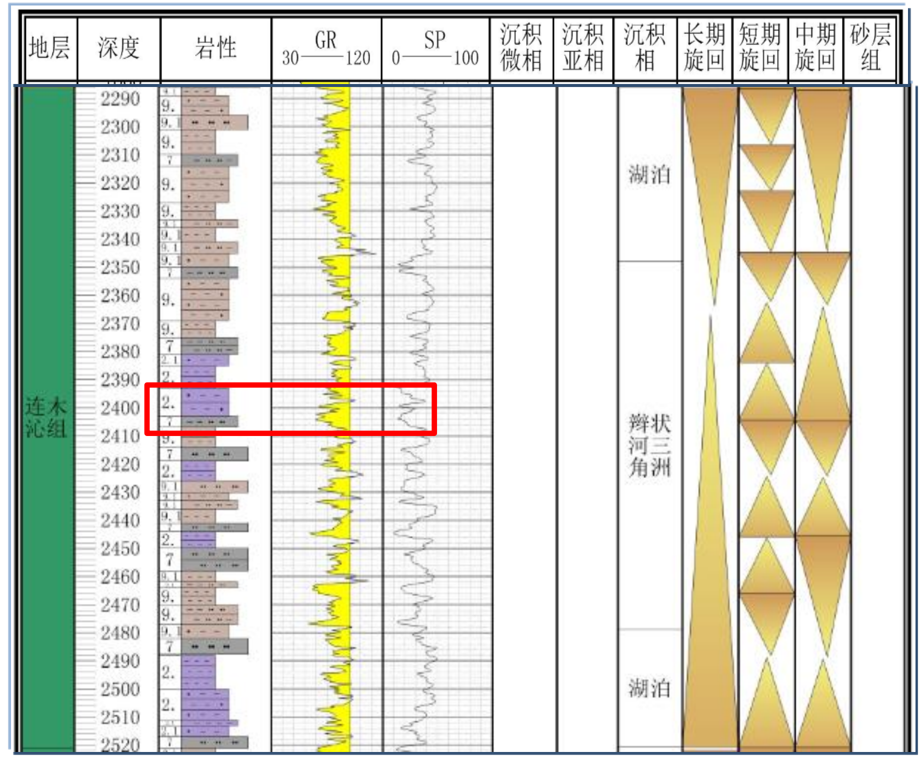
侏罗系Jurassic
Bottom boundary depth: 6650-7500 m

High precision gravity exploration



Sequential stratigraphy correlation

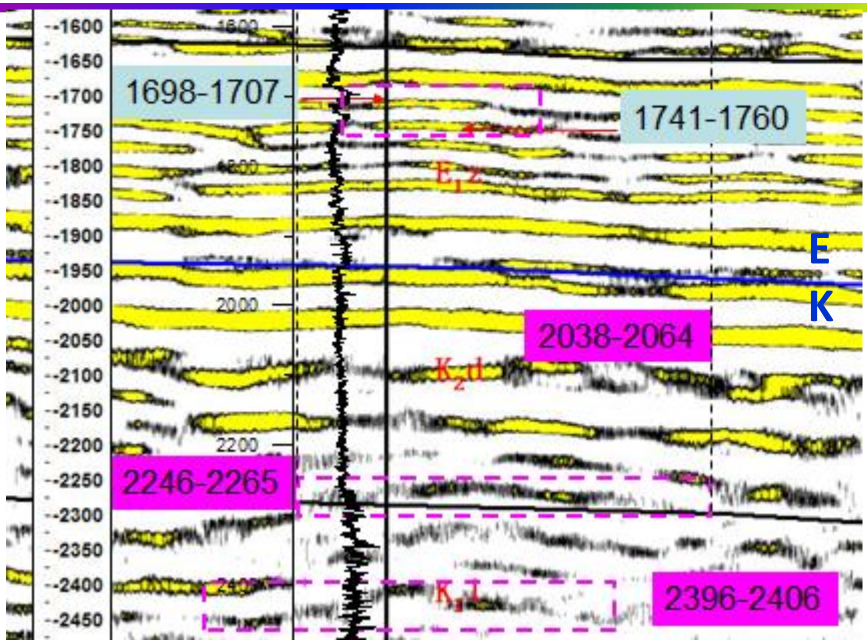




Potential perforated intervals：

- ✓ **2038.00-2065**
- ✓ **2246.50-2265**
- ✓ **2392.00-2407**

2D seismic exploration and downhole test

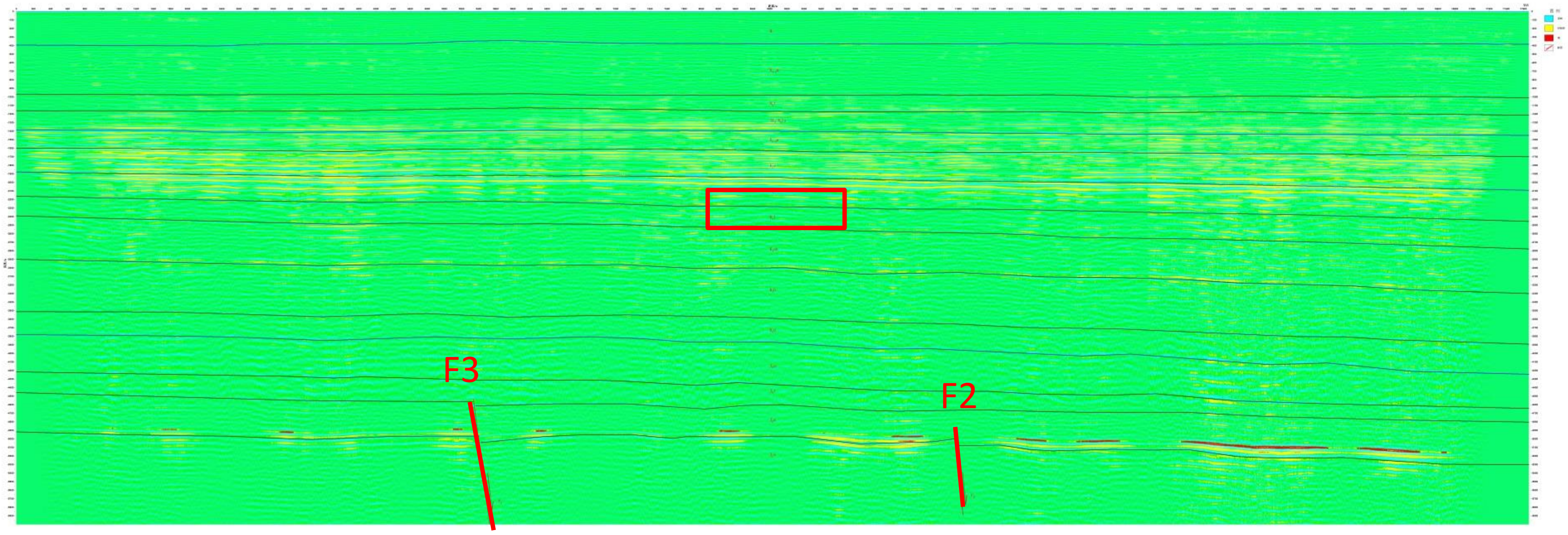


- 地层平缓
- 第1层砂层不明显
- 第2层和第3层有明显的砂岩透镜体

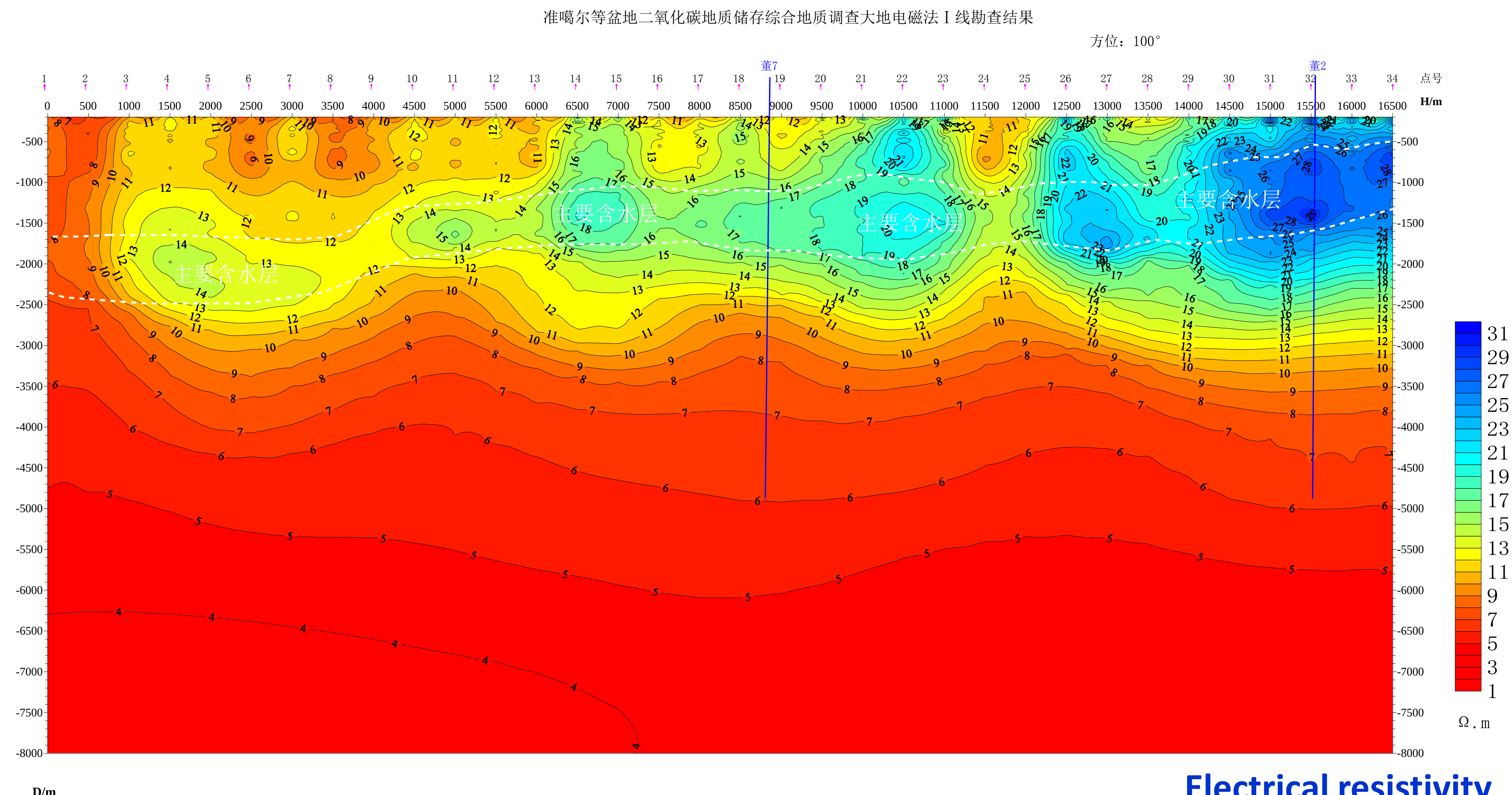
✓ **2038.00-2065 m：in progress**

✓ **2246.50-2265 m：hydraulic discharge is about 42 m³/d，TDS 40g/L，CaCl2**

✓ **2392.00-2407 m：hydraulic discharge is about 41 m³/d，TDS 30g/L，CaCl2**



Magnetotelluric sounding (MT) exploration



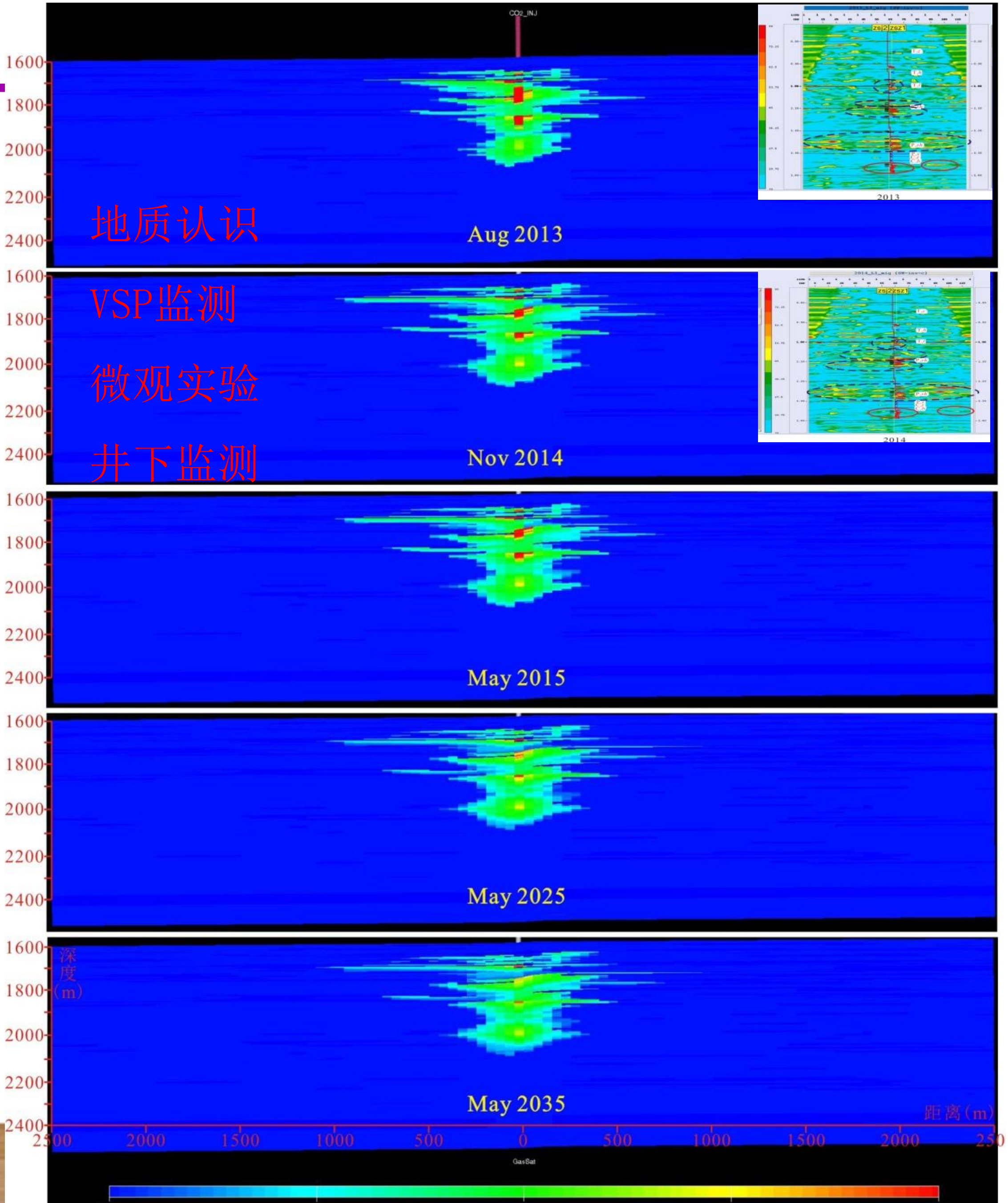
Electrical resistivity

China Australia Geological Storage of CO_2

中澳二氧化碳地质封存

Next work plan

- ✓ 技术经济分析（乌伦古坳陷适宜区和D7井）
  On basis of studies of source-sink matching, choose the suitable sites in Ulungur depression in the Junggar Basin and D7 well for technical and economic analysis of CO_2-EWR
- ✓ D7井储层表征（包括理论地下水资源量和CO_2封存量）
  Reservoir characterization, including assessment of groundwater resources and theoretical potential of CO_2 storage of 3 main reservoirs
- ✓ D7井CO_2-EWR方案模拟
  Numerical simulation of CO_2-EWR plan in D7 well, and choose the most suitable reservoir for possible ″push-pull” test
- ✓ 进一步合作
  Further cooperation in reservoir characterization, numerical simulation, monitoring, et al. of CO_2-EWR or saline aquifer CO_2 storage

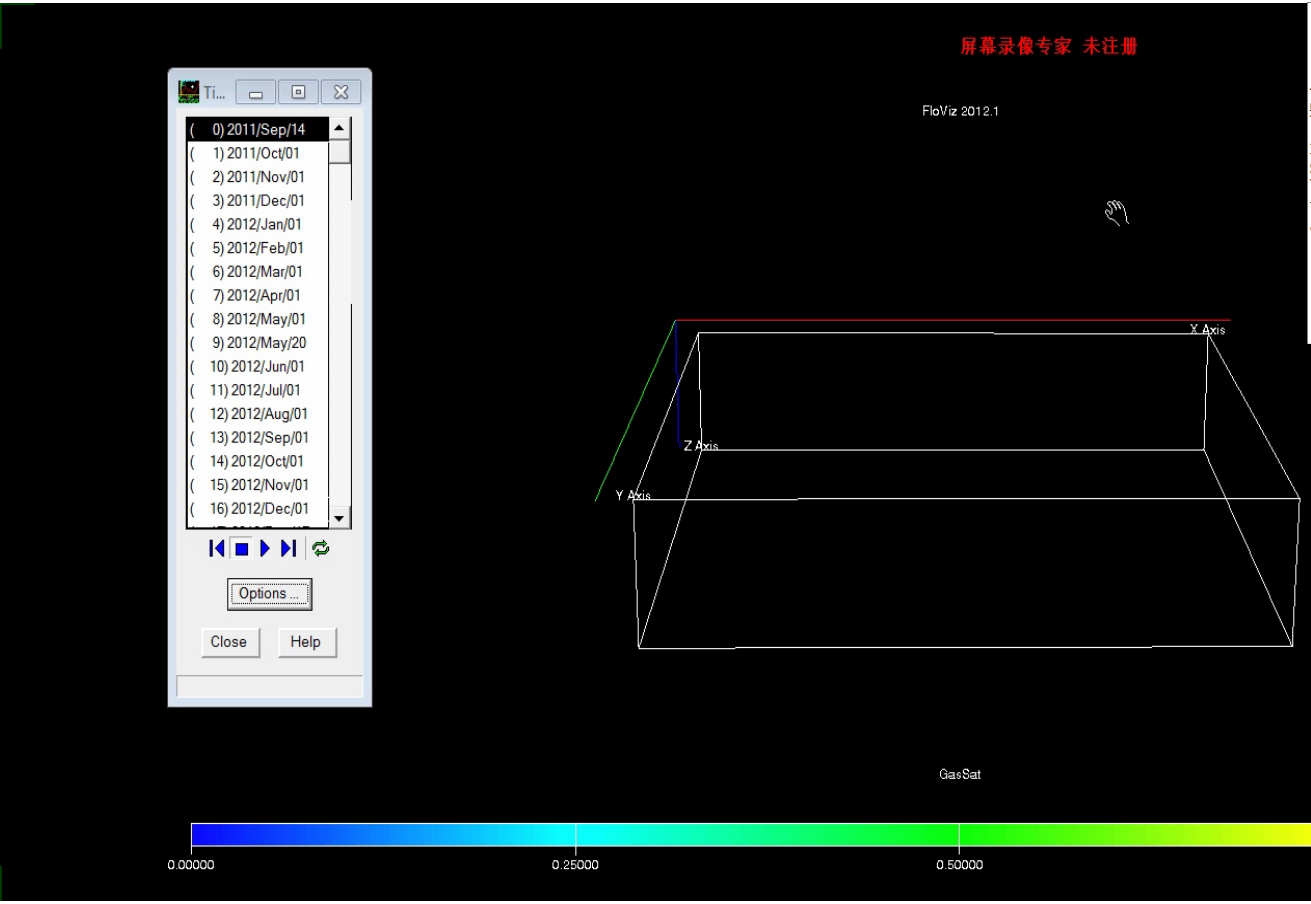


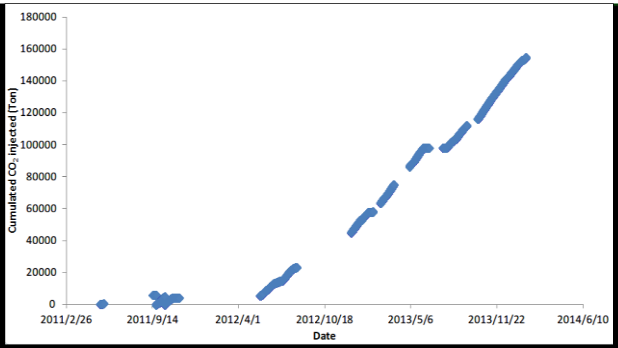
神华CCS示范工程

Shenhua CCS Project

- CO_2由注入井向西北方向运移扩散，刘家沟组初始运移距离较小，但到2014年11月，随着CO_2注入量的增大，刘家沟组运移距离增大较明显，马家沟组注入量则极少。
- 垂向上，主要表现为CO_2向储层上部运动，因此刘家沟组和石千峰组上部吸收的CO_2最多。从CO_2分布饱和度模拟结果来看，注入井射孔段较高，局部达90%以上。
- 数值模拟与L1 VSP地震监测数据之间的差异在于，数值模拟结果显示石千峰组运移距离最远，但地震预测结果显示石盒子组运移距离最远。
- 推测可能为模型中CO_2上浮的模型或参数设置问题？

CO2 flow underground in Shenhua CCS Demo-project storage site





CO_2晕空间演化规律

Thanks for your attention