Assessment on CO_2 Storage in Deep Saline Formation of Offshore Bohai Basin

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Contents

1. Introduction

Circum-Bohai-Sea region

One of the most densely populated and economically prosperous regions in China;
One of the highest CO_2 emission regions in China;
Three provinces in this region, i.e. Shandong, Hebei and Liaoning, are ranked 1st, 3rd and 4th respectively in terms of CO_2 emission in China (statistics in 2006);
The CO_2 emission in this region will account for nearly 30% of the total emission in China, if the emissions in Beijing and Tianjin are included.

It is urgent to reduce the CO_2 emission effectively for the environment protection and sustained development of social economy of the Circum-Bohai-SeaRegion.

1. Introduction

CO_2 Capture and Geological Storage (CCS)

- a new-coming technique to mitigate the greenhouse gas emission;
- CO_2 is captured and injected back into deep saline aquifers, abandoned oil and gas fields or unminable coal beds.

Advantages:

✓effectively and safely reduced
✓large mass
✓long term

1. Introduction

Offshore geological storage

- has technically more advantages than onshore geological storage (Schrag, 2009);
- relatively easy pressure management and less impact on population, land and groundwater ;
- may cause higher costs under the current technological level.

a more promising CO_2 storage option in the future (Schrag, 2009; Zhou et al., 2011).

1. Introduction

Bohai Basin: many favorable conditions to implement offshore geological storage:

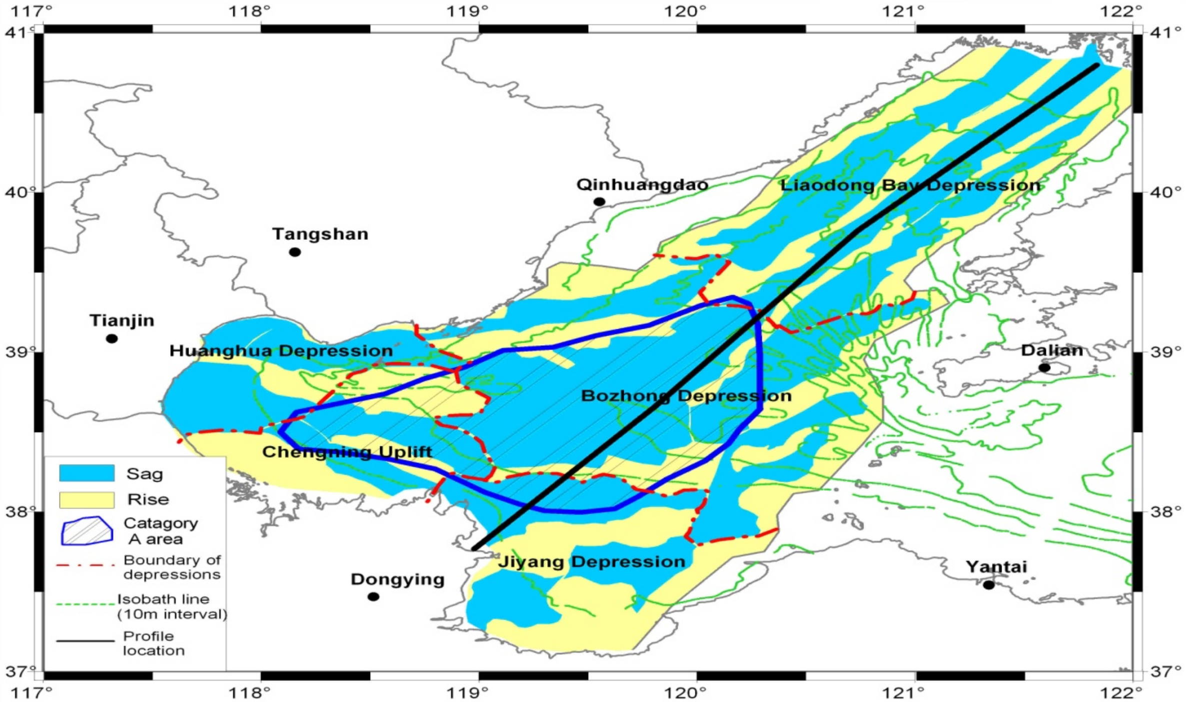
- the huge thickness of sedimentary deposits
- the rich data and techniques in accumulation of oil and gas exploration
- the close distance to CO_2 sources

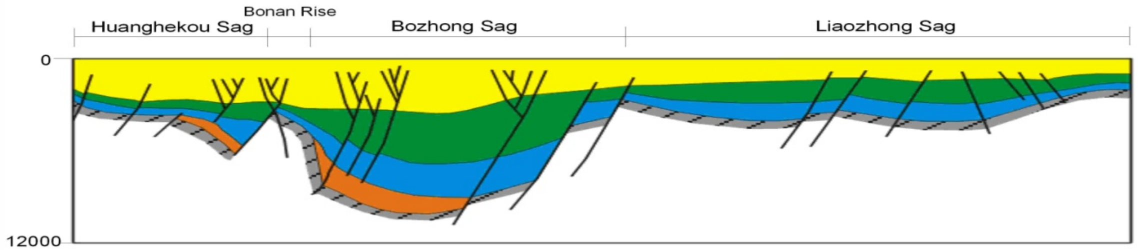
Our Work

Evaluate the potential CO_2 storage capacity of the Bohai Basin using the published data and references to meet the potential demands of CCS in this region.

2. Geological background and CO_2 storage conditions

Geological settings



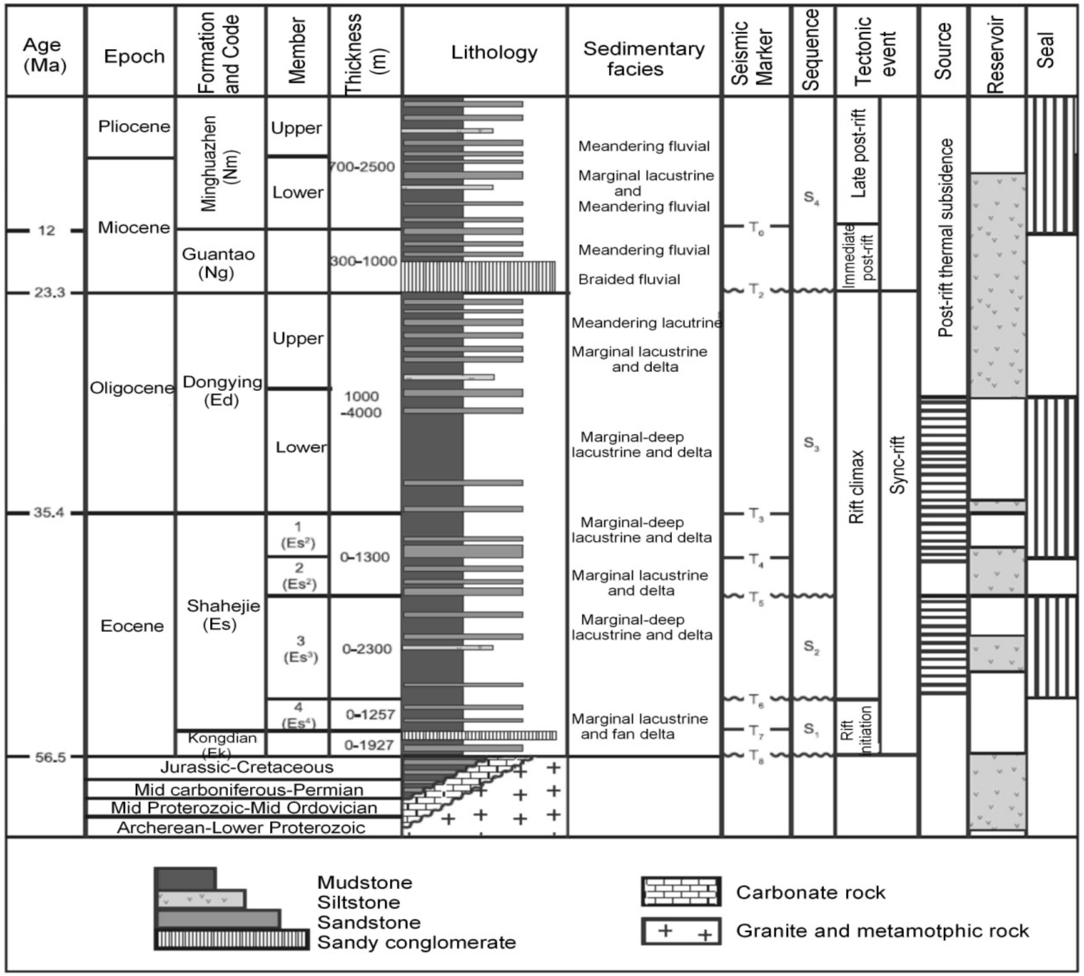


Cenozoic stratigraphy

Cenozoic stratum of the Bohai Basin is mainly made up of terrigenous clastic rocks. Its maximal thickness is close to 12000m at the Bozhong sag, in which the Neogene exceeds 5km at most (Li & Lu, 2002). During the long and complex geological evolution in Paleogene rifting and Neogene post-rifting and depressing, diverse sedimentary systems were formed, including alluvial fan, fan delta, braided river delta, river delta, submarine fan, sublacustrine fan, lake and extremely shallow water delta of Neogene, etc.(Yang & Xu, 2004; Zhu et al., 2009). The uplift in the basin and circumferential highland provide large amount of terrigenous clastic substances.

2. Geological background and CO_2 storage conditions

Petroleum geology



CO_2 storage conditions

There exist several sets of storage-seal assemblages in the Bohai Basin. The first is the mudstone of the Minghuazhen Formation, which is used as the seal of the reservoirs of the Minghuazhen Formation, the Guantao Formation and the upper Dongying Formation. The second is the mudstone of the lower Dongying Formation, which is used as the seal of the reservoirs of the lower Dongying Formation, the first member of the Shahejie Formation. The third is the self-reserved and self-capped assemblage of the third member of the Shahejie Formation.

Method of storage capacity calculation

We use the method proposed by USDOE (2008), which fits better the data collected in the Bohai Basin. According to USDOE (2008), the effective storage capacity can be expressed as:

$$M_{CO_2} = A \times h \times \varphi \times \rho_{CO_2} \times E \qquad (1)$$

M_{CO2} is CO_2 effective storage capacity
A is reservoir area
h is reservoir thickness
φ is porosity of reservoir
ρ_{CO2} is density of CO_2 in reservoir
E is effective coefficient of storage

Method of storage capacity calculation

In fact, equation (1) can also be expressed in the integral mode, if the reservoir can be considered as the assemblage of many 3D unit dxdydz, with porosity $\varphi(x, y, z)$, sandstone percentage $\delta(x, y, z)$ and CO2 density $\rho_{CO2}(x, y, z)$.

$$M_{CO_2} = E \times \iiint \varphi(x, y, z) \times \delta(x, y, z) \times \rho_{CO_2}(x, y, z) \times dxdydz \qquad (2)$$

In discrete mode, equation (2) can be expressed as

$$M_{CO_2} = E \times \sum_i \left(\Delta A_i \times \sum_j \Delta h_{ij} \times \varphi_{ij} \times \delta_{ij} \times \rho_{ij} \right) \qquad (3)$$

supposing that the target reservoir is made up of many cubic units with area of ΔA_i and thickness of Δh_{ij}, their center burying depth is d_{ij}, sandstone percentage is δ_{ij}, porosity is φ_{ij}, temperature is Tij and pressure is Pij. Here ρ_{CO2} is CO_2 density at temperature of T_{ij} and pressure of P_{ij}.

3. Method and data source

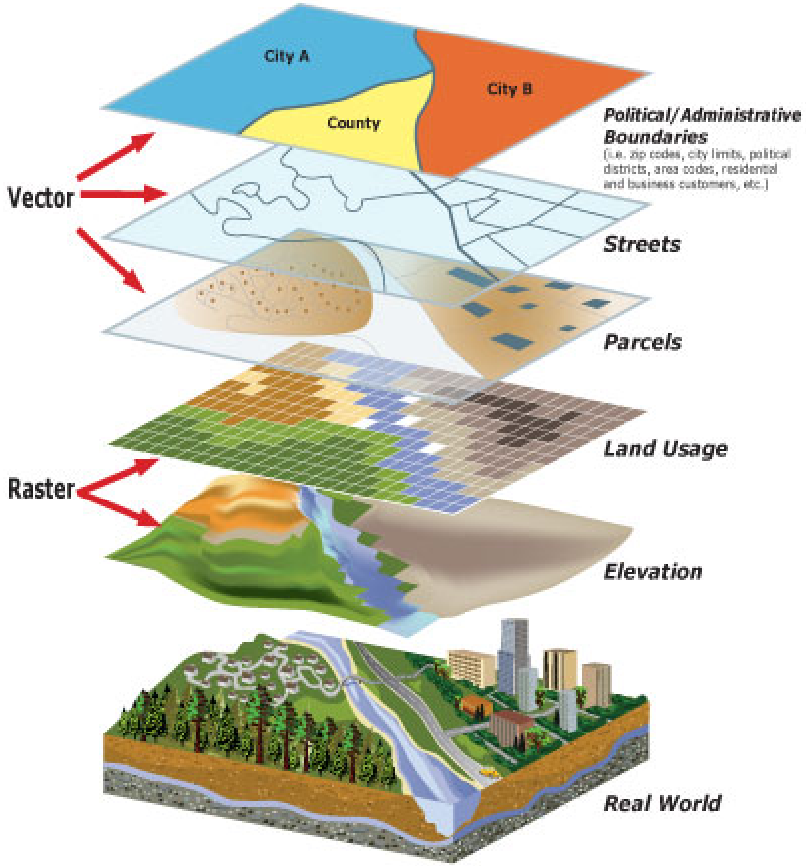
Data source

The exploratory well is sparse in the Bohai Basin, only about 50 per 10,000 km2. Even the evaluation wells are included, there is only 100 wells per 10,000 km2. Therefore, the basin is in a low to medium exploration degree. In order to calculate the CO_2 storage capacity, it is necessary to simplify the selection of parameters so that the data insufficiency can be implemented. In this study, the data of reservoir thickness, physical features and geothermal field in the Bohai Basin are collected,

GIS

A geographic information system is a system designed to capture, store, manipulate, analyze, manage, and present all types of geographical data.

GIS data model



Data process

- **Map Scan**: paper to images in computer
- **Map Digitization**: images to vectors, such as points, polyline, polygon, ……
- **Coordinate transformation**: using uniform coordinate in order to display and calculate multi-source and heterogenous spatial data
- **Griding:** interpolate vectors to rasters in uniform cell-size and spatial boundary

Quadrangular prism

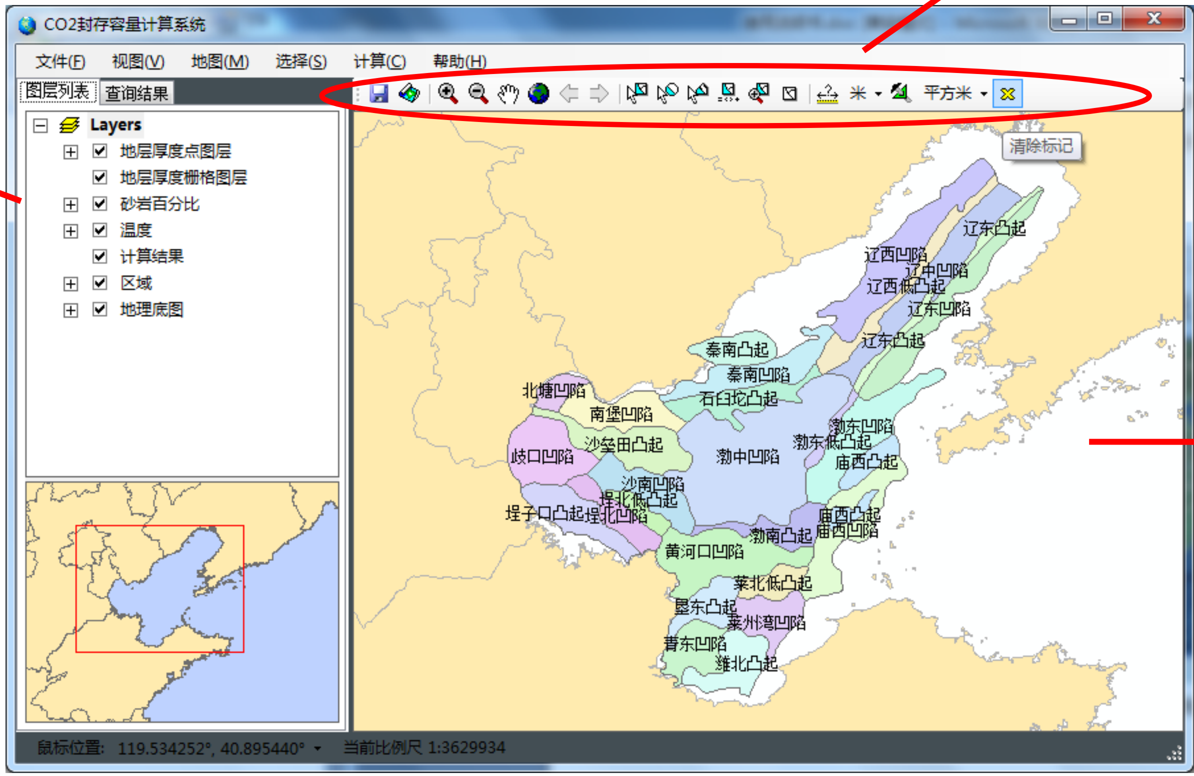
- The cells at the same coordinate of both upper interface raster and lower interface raster of one stratum can construct a quadrangular prism as a calculate unit;
- Each quadrangular prism can be divided vertically into multiple units to improve the resolution of calculation;
- Calculate the storage capacity of each Quadrangular units using the Arcobject interface - IRaster;
- Summarize the results of each Quadrangular units.

5. System introduction

Main interface

toolbar

group layer



main view

navigation view

5. System introduction

Storage capacity calculation function

step 1: stratum parameter configuration

5. System introduction

Storage capacity calculation function

step 2: stratum temperature configuration

5. System introduction

Storage capacity calculation function

step 3: calculation parameter configuration

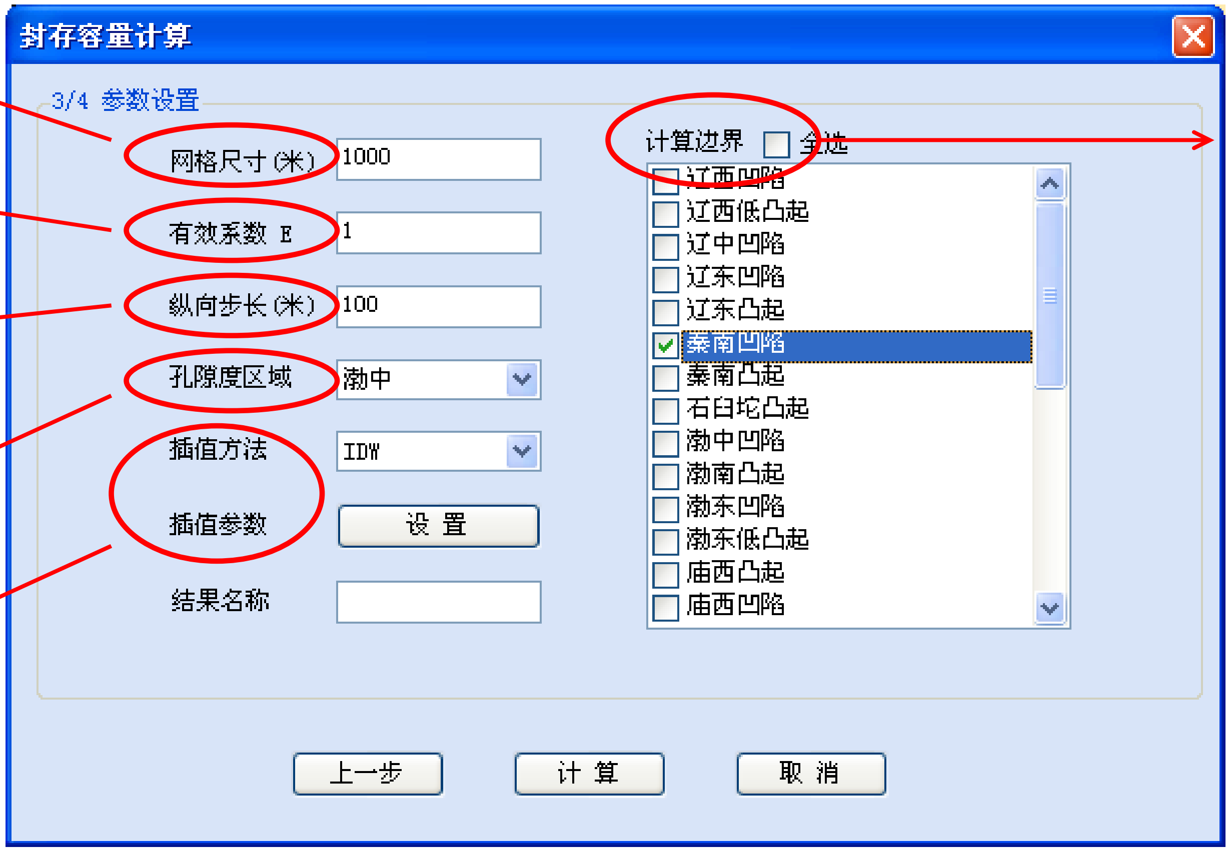
grid cell size

effective coefficient

vertical interval

voidage value region

interpolation configuration

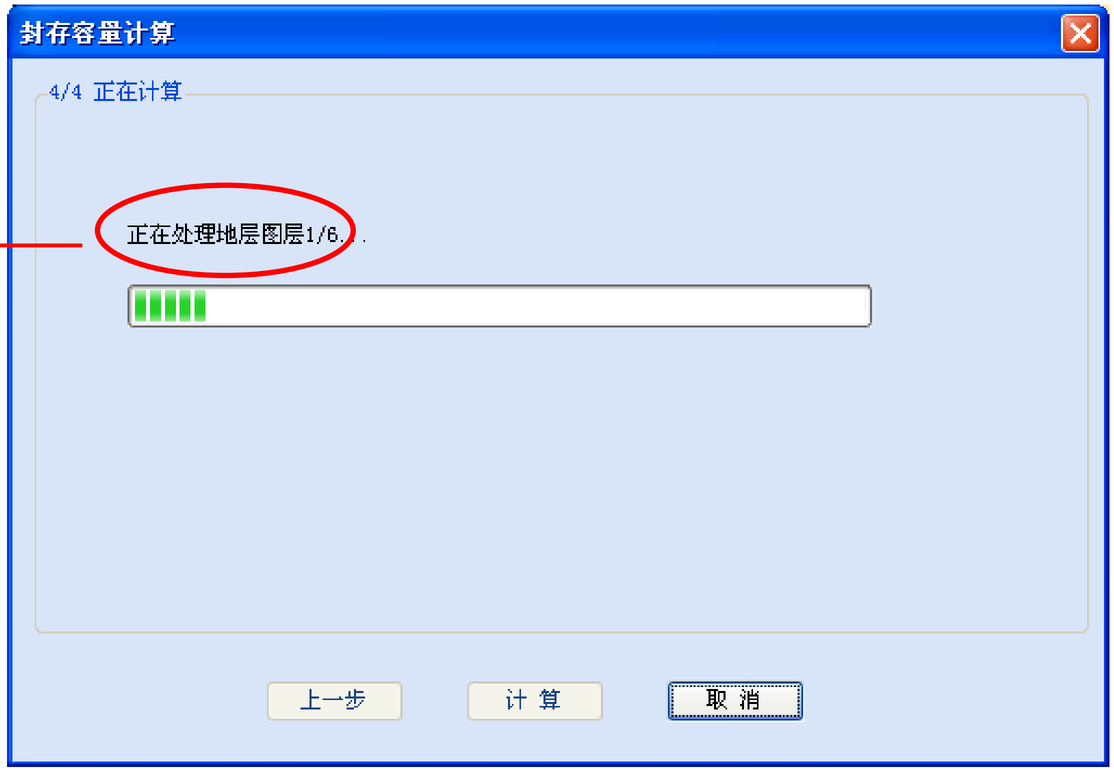


calculation boundary selection

Storage capacity calculation function

step 4: computing

computing progress



Storage capacity calculation function

text results

All parameter values during the calculation are stored in text format for reference

计算结果A.txt - 记事本

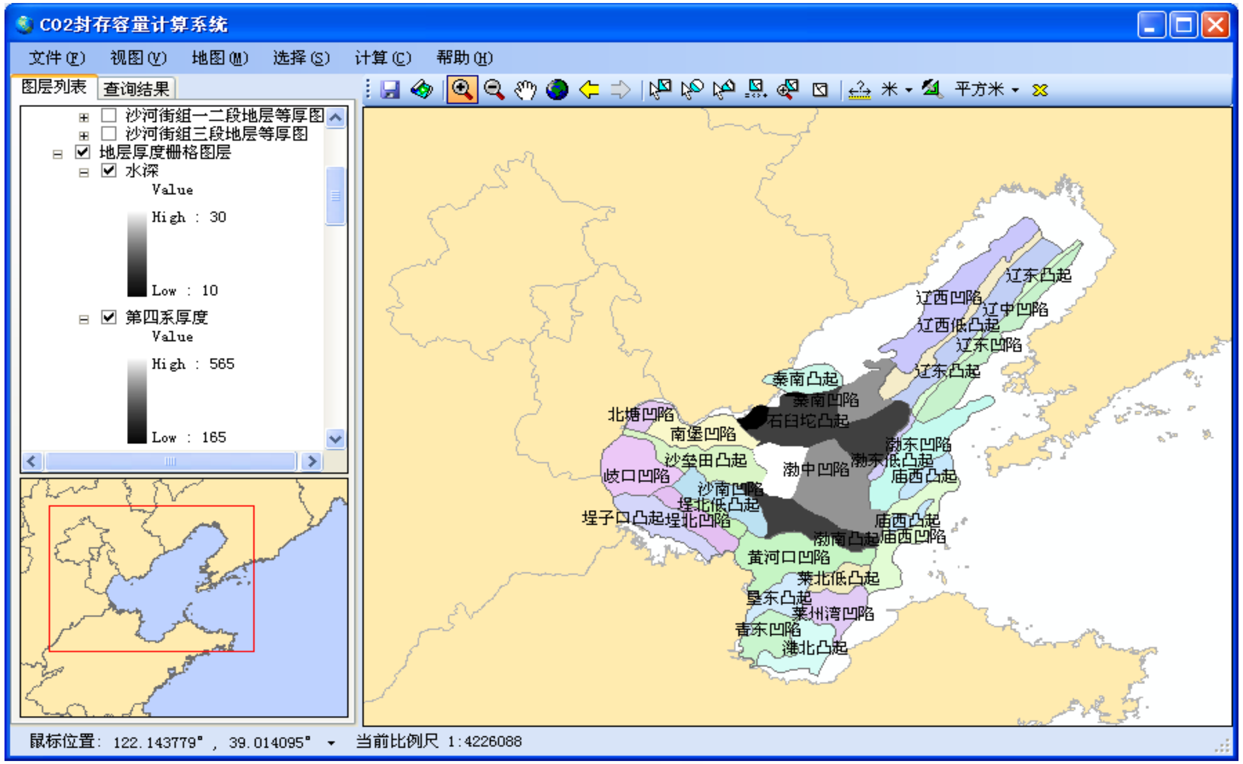
文件(F) 编辑(E) 格式(O) 查看(V) 帮助(H)

```
x	y	经度	纬度	临界埋深	海底温度	水深	第1层埋深	第2层埋深	第3层埋深	第4层埋深
第5层埋深	第6层埋深	第1层容量	第2层容量	第3层容量	第4层容量	第5层容量	第6层容量
总量_亿吨
250662.083624002	4387638.77604556	120.095990940075	39.6022190283105	728.061224489796	15
25	474.266143798828	1292.28555297852	1542.28555297852	2121.06057739258	2623.70883178711
3023.70883178711	0	0.81987547868069	0.294185033326787	0.808901196455269	0.552746941382159
0.366169091162135	2.84187774146625
251662.083624002	4387638.77604556	120.107623856249	39.6025094412297	728.061224489796	15
25	472.272247314453	1308.48110961914	1558.48110961914	2139.07864379883	2642.22946166992
3042.22946166992	0	0.841638338546252	0.288312380440656	0.797456598238071	0.556479763985656
0.360068996554589	2.84395607776522
252662.083624002	4387638.77604556	120.119256940532	39.6027986912013	728.061224489796	15
25	427.711822509766	1264.29165649414	1514.29165649414	2100.71694946289	2604.37142944336
3004.37142944336	0	0.782182075614253	0.291633293807916	0.816685764237604	0.539013970770896
0.370059916054299	2.79957502048497
253662.083624002	4387638.77604556	120.130890192253	39.6030867781756	728.061224489796	15
25	323.575073242188	1142.18670654297	1392.18670654297	1989.99542236328	2494.15493774414
2894.15493774414	0	0.614611388567503	0.315532317540099	0.88763817855966	0.575587381333047
0.395496494650305	2.78886576065061
254662.083624002	4387638.77604556	120.142523610739	39.6033737021028	728.061224489796	15
25	245.945251464844	1064.64105224609	1314.64105224609	1915.44067382813	2420.1068115234
2820.10681152344	0	0.508165762264325	0.31550908831463	0.885119236337428	0.602719491137359
0.400623665460793	2.71213724351453
255662.083624002	4387638.77604556	120.154157195319	39.6036594629338	728.061224489796	15
25	200.673202514648	1019.43101501465	1269.43101501465	1871.58409118652	2395.36198425293
2795.36198425293	0	0.440142834545964	0.323236348536755	0.94188477738216	0.622871324696612
0.417750061305958	2.74588534646745
256662.083624002	4387638.77604556	120.165790945321	39.6039440606193	728.061224489796	15
25	165	983.79052734375	1233.79052734375	1837.13354492188	2361.28369140625	2761.28369140625	0
```

5. System introduction

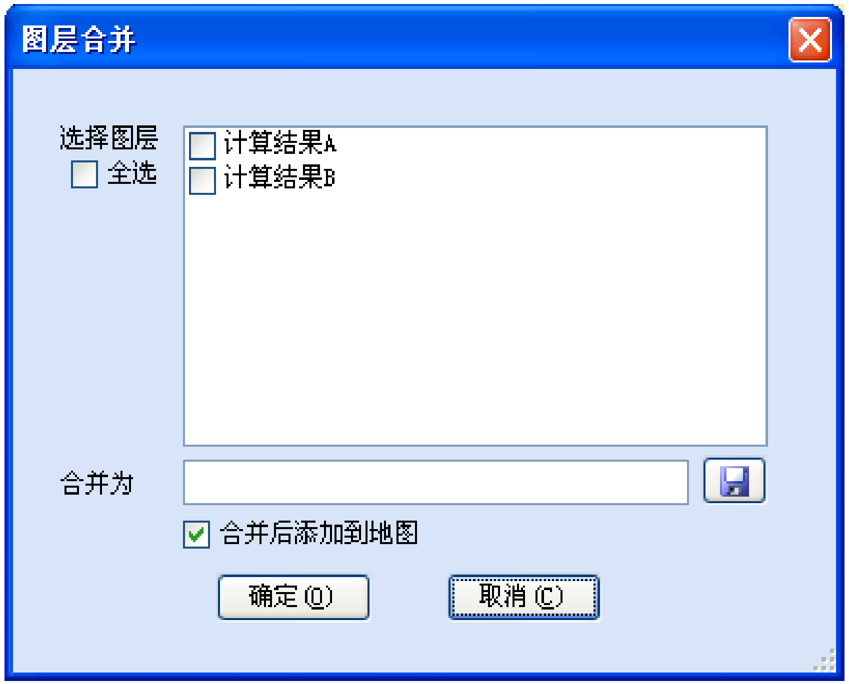
Storage capacity calculation function

spatial layer results

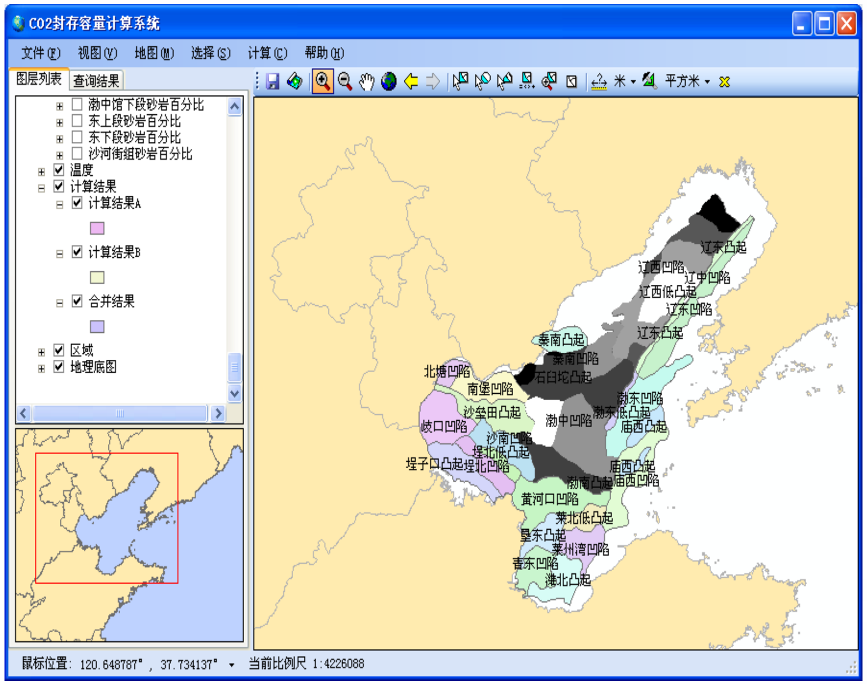


5. System introduction

Merge of multiple spatial layer results



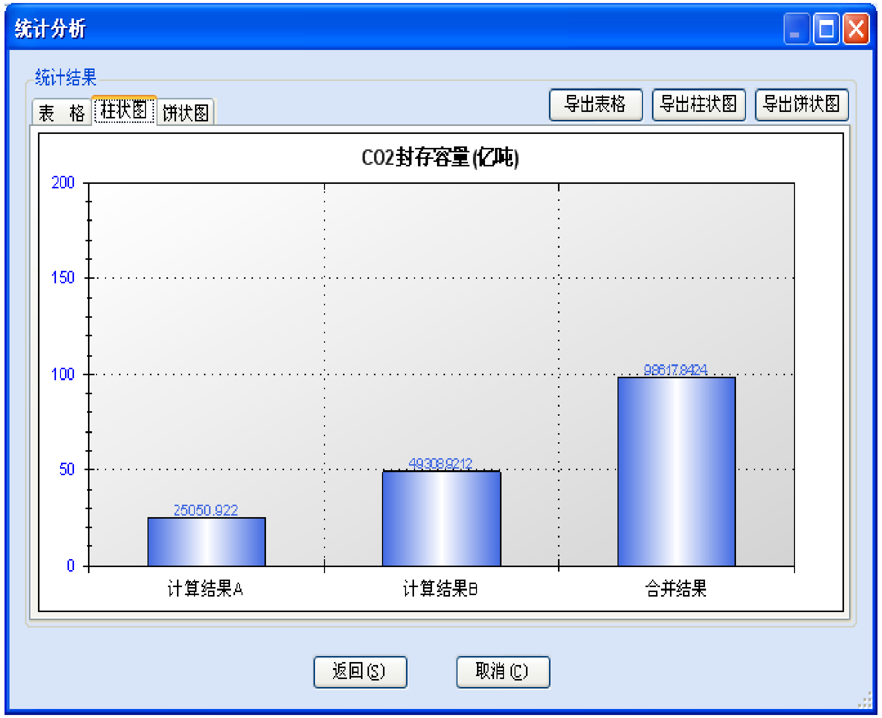
layer selection

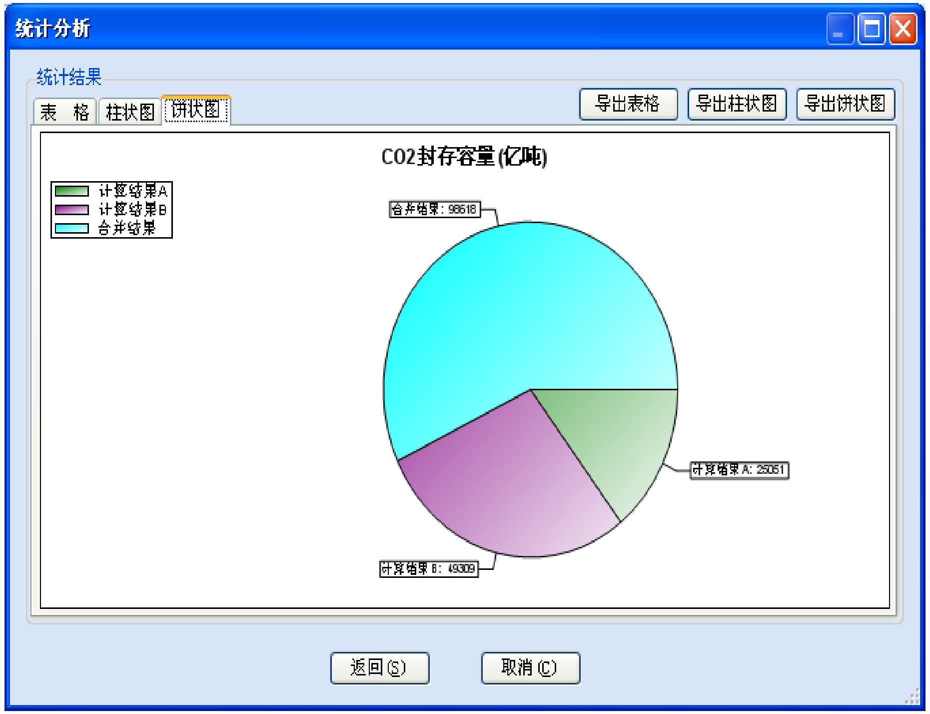


merge result

5. System introduction

Statistics

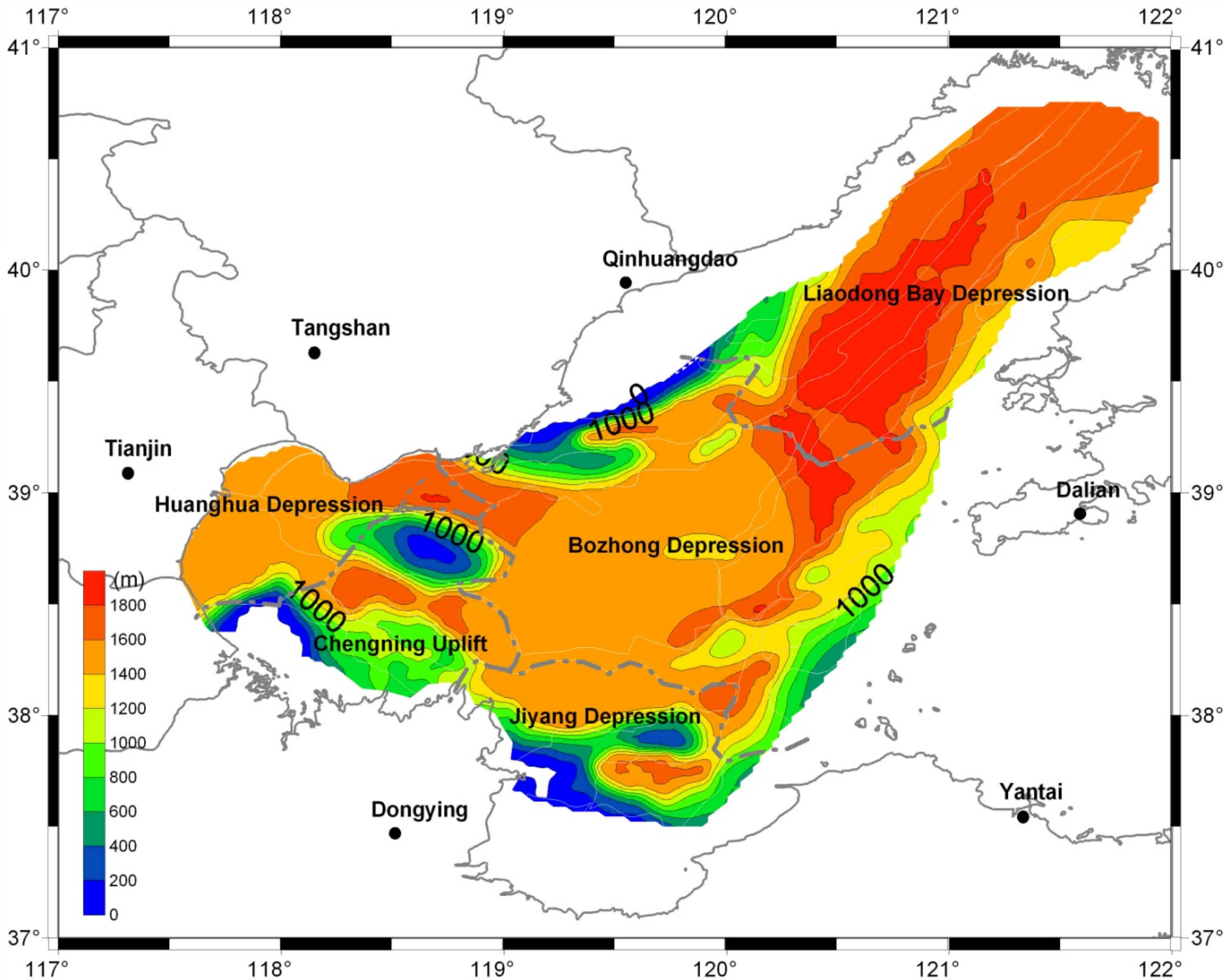




Total CO_2 storage capacity of Bohai Basin

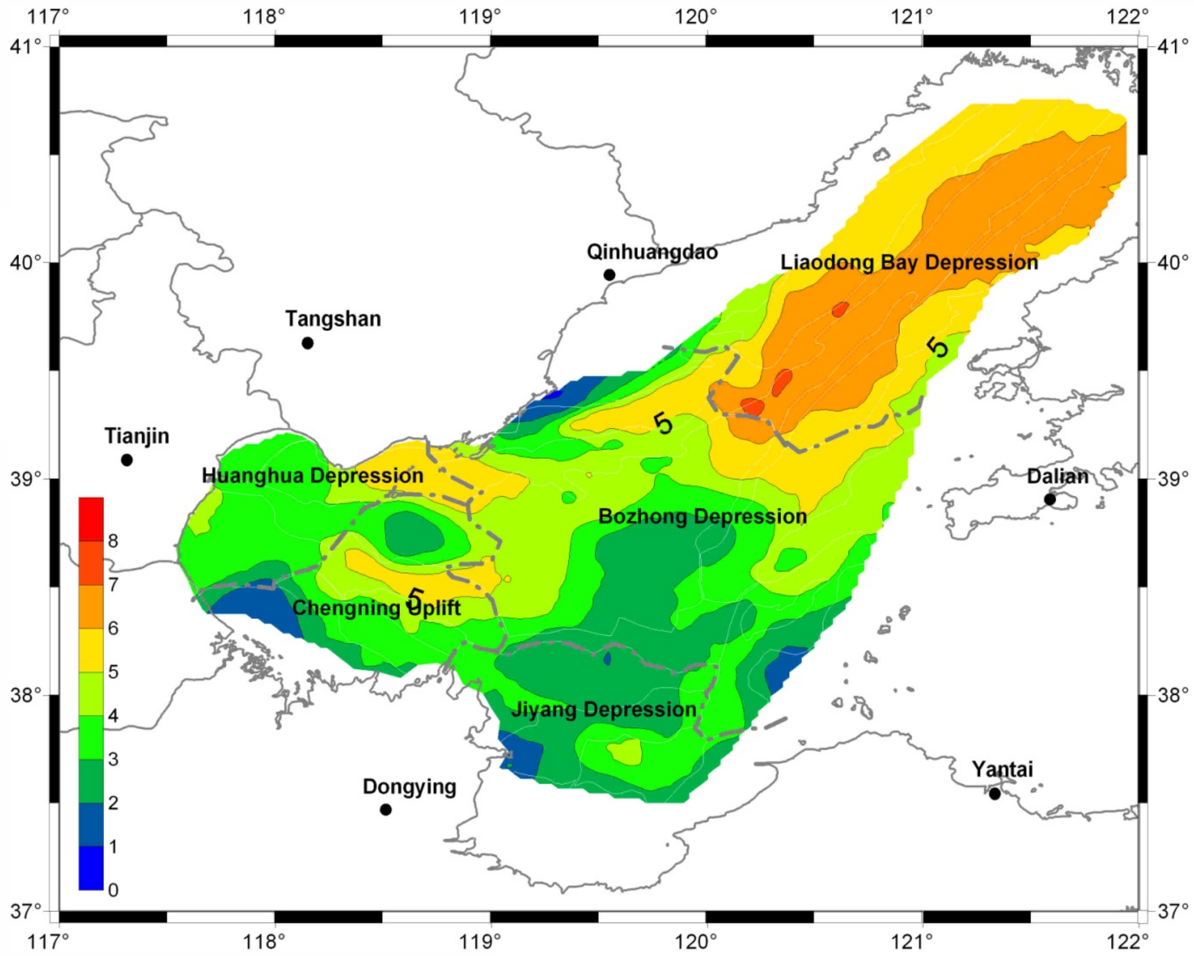
The total reservoir pore volume between critical depth and 3500m depth for each stratigraphical unit from lower Minghuazhen Formation the third member of Shahejie Formation is $1.6\times10^{13}m^3$, where totally $963\sim3851\times10^8$t CO_2 can be stored, with the mean value 2504×10^8t. From the critical depth to the lower interface of the third member of Shahejie Formation, the maximum sediment thickness is nearly 10,000 meters, but the total pore volume is $1.7\times10^{13}m^3$, only increase slightly in comparison with the reservoir over 3500m, and the mean CO_2 storage capacity is 2675×10^8t, with an increase of 6% over stratum shallower than 3500m. The total pore volume of the reservoir at depths from critical depth to 2500m is $1.3\times10^{13}m^3$, and the mean value of total storage capacity is 2037×10^8t, and both pore volume and storage capacity decrease by 20% or more over the whole Cenozoic reservoir. Thus, it may not cause serious underestimation of capacity if the depth of 3500m was regarded as the lower limit of storage depth.

6. Results and discussion



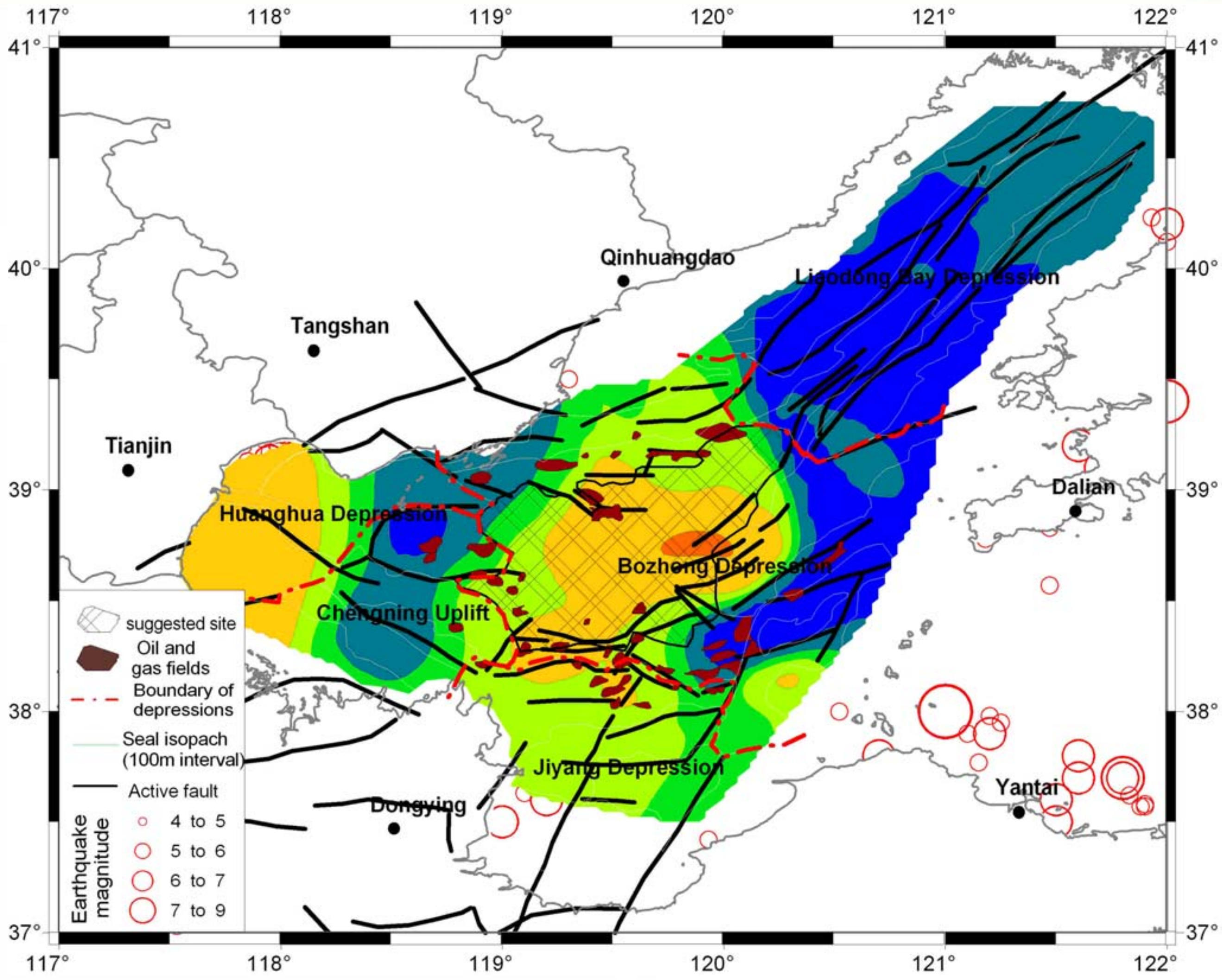
(Lower Minghuazhen to 3rd Shahejie Formation) between the depth CO_2 reaching supercritical states to 3500m

6. Results and discussion



Contour map of CSCD (CO_2 storage capacity density) in Bohai Basin, unit in $10^4 t/km^2$

6. Results and discussion



The suggested potential storage area in Bohai Basin

Thanks!