



CO₂ and “Green Oil”

Mingyuan Li

EOR Research Centre
China University of Petroleum, Beijing
Jan. 21 2010



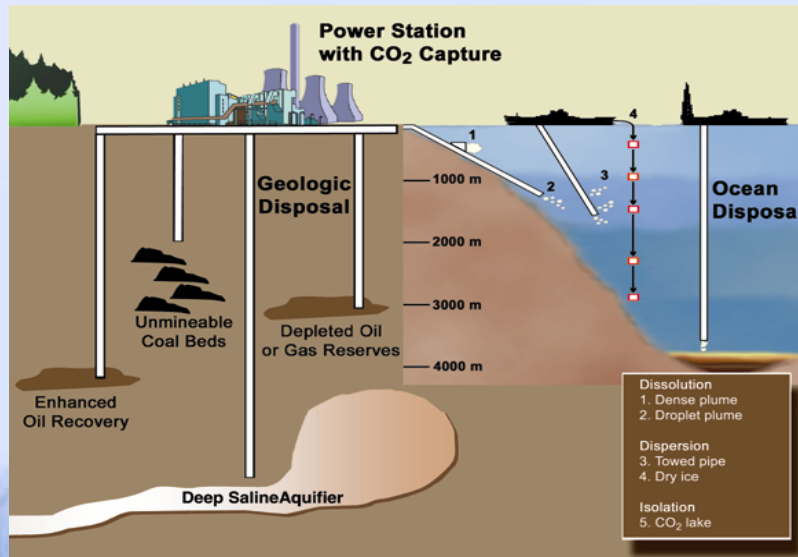
Outline

- ▣ CO₂ and CCS
- ▣ CO₂ and EOR
- ▣ CO₂ EOR and “Green Oil”
- ▣ Could Oil be “Green”
- ▣ CO₂ EOR+Storage and “Green Oil”
- ▣ “Green oil” in the future of China
- ▣ Strategy of CO₂ storage in China



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

CO₂ and CCS

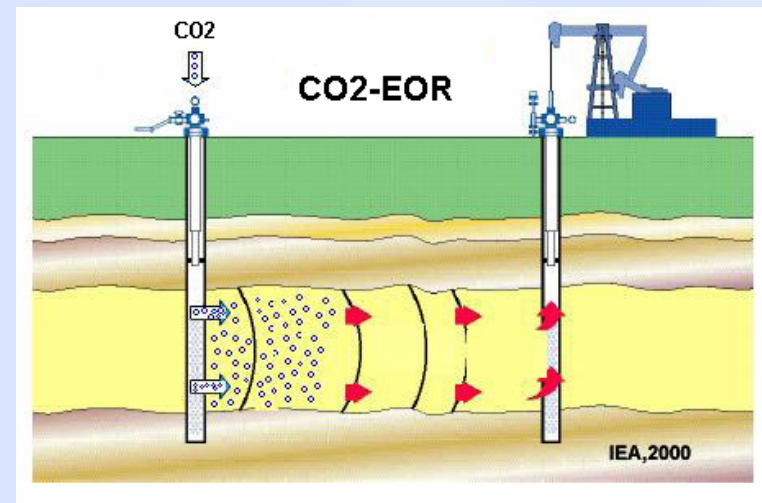


Capture:

CO₂ from power, steel, cement, refinery and chemical plants.

Storage:

- Deep saline aquifer
- Depleted oil and gas reservoirs
- **CO₂-EOR**
- Coal seams

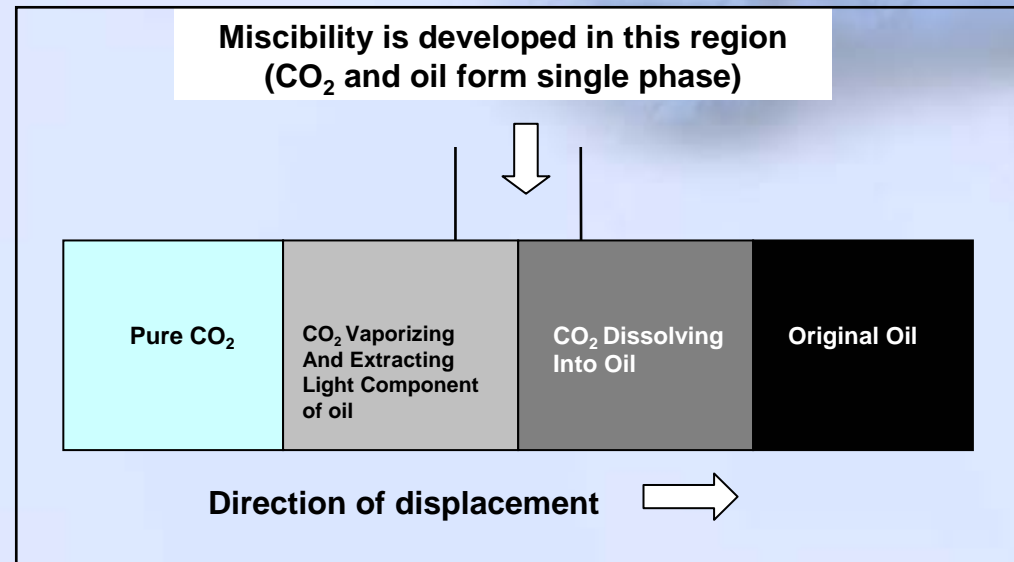
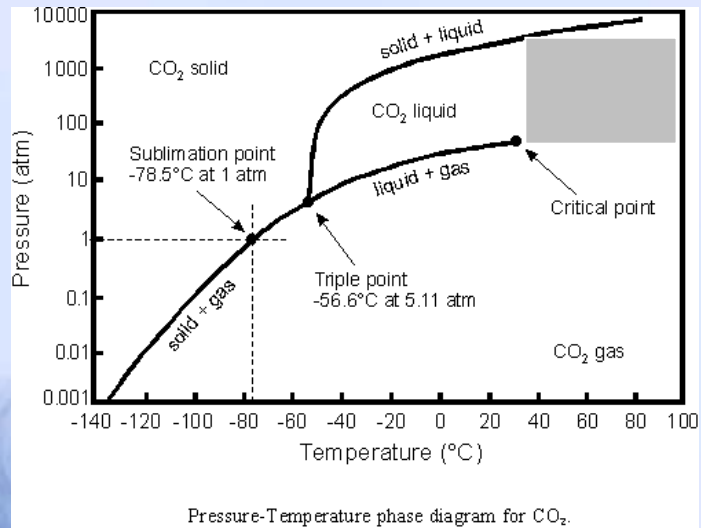


CO₂-EOR could offset the cost of CO₂ storage or CCS



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

CO₂ and EOR



Oil recovery by CO₂- EOR in US

Time	1986	1990	2000	2008
Production of oil (t/d)	4500	15000	30000	38500
Production of oil (Mt/y)	1.65	5.0	11.0	14.0



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

CO₂ EOR and “Green Oil”

2.68 t of CO₂ is released when 1 t of oil is combusted.

If CO₂ used for **EOR** to produce 1 t oil are more than 2.68 t, the oil produced could be “Green Oil”.

The release of CO₂ from the oil will be zero or negative.

Green Oil - CO₂ released from the oil produced by CO₂ EOR is equal to the CO₂ stored in the reservoir. The oil is 100% carbon free.



Could oil be “Green” ?

If 60% of the CO₂ injected into oil bearing reservoir could be stored in the reservoirs during EOR process:

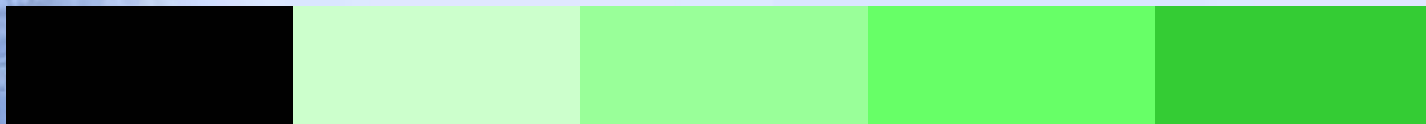
The oil produced in US by CO₂ EOR is 63% carbon free.

The oil produced in Weyburn Canada by CO₂ EOR is 30% carbon free.

The oil produced in China by CO₂ EOR(pilot) is 37- 49% carbon free.

Oil

Green Oil



The oil is only “light green” with lower carbon



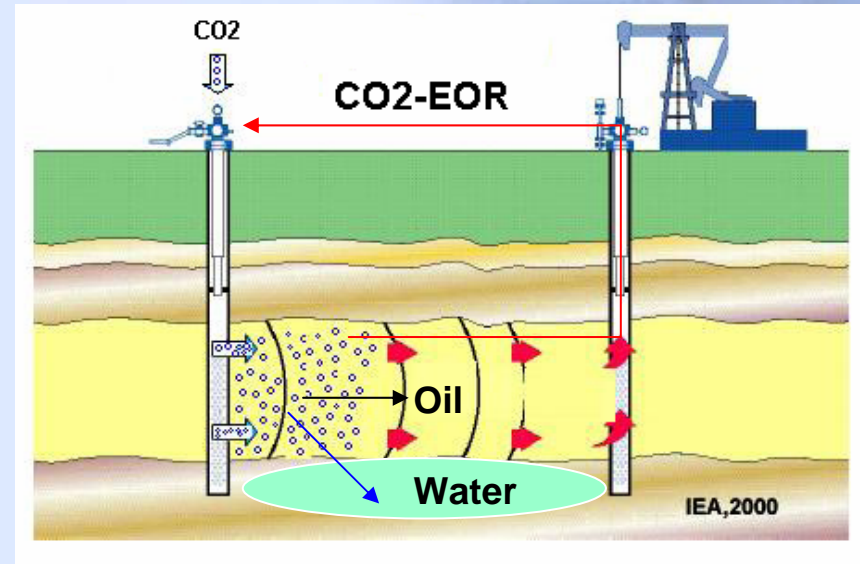
中国石油大学
CHINA UNIVERSITY OF PETROLEUM

CO₂ EOR + Storage and “Green Oil”

Methodologies

Conditions for only CO₂-EOR:

- Low permeability reservoirs
- Heterogenous reservoirs
- Higher viscosity of oil
- Low injection rate of CO₂
- Part of CO₂ trapped in the reservoirs
- Part of CO₂ come out of production wells(about 40%)
- Part of CO₂ dissolved in the oil in the reservoirs
- Part of CO₂ dissolved in the water of the reservoirs



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

CO₂ EOR + Storage:

Assessment model for CO₂ storage potential (CUP)

$$M_{(\text{CO}_2)} = M_1 + M_2 + M_3 + M_4$$

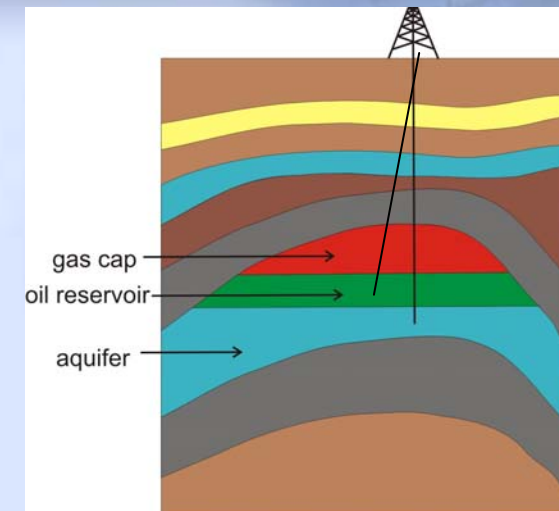
$M_{(\text{CO}_2)}$ - total storage capacity of CO₂ (m³)

M_1 - storage capacity of CO₂ dissolved in oil and water in oil bearing reservoir

M_2 - storage capacity of CO₂ dissolved in formation water

M_3 - storage capacity of CO₂ in oil bearing reservoir during CO₂ flooding

M_4 - storage capacity of CO₂ reacted with rock



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

$$M_{(CO_2)} = E_f \times A \times h \times \varphi \times [S_o \times R_{o(CO_2)} + (1 - S_o) \times R_{w(CO_2)}] + h \times A \times \varphi \times S_w + (M_p \times 4\% / \rho_f)$$

E_f —overall sweep efficiency, $E_f=5-25\%$;

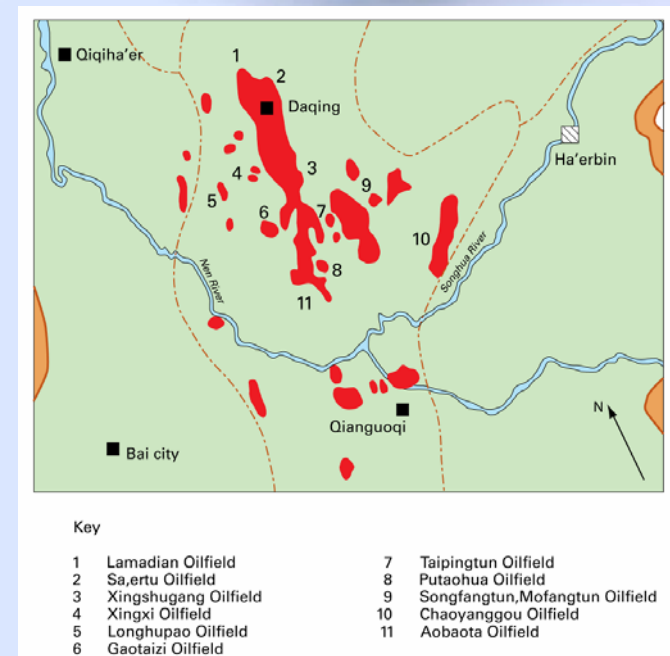
S_o —oil saturation in reservoir,

$R_{o(CO_2)}$ —CO₂ solubility in oil, 12-18%

$R_{w(CO_2)}$ —CO₂ solubility in water, 3-5%

S_w —CO₂ solubility in formation water, 3-5%

M_p —residual oil in reservoir (10⁴t)



Daqing oil field

CO₂ storage capacity in oil bearing reservoirs of Daqing oil field complex

Oil field	M_1 ($\times 10^6 \text{m}^3$)	M_1/M (%)	M_2 ($\times 10^6 \text{m}^3$)	M_2/M (%)	M_3 ($\times 10^6 \text{m}^3$)	M_3/M (%)	Total ($\times 10^6 \text{m}^3$)
Lamadian	43.27	17.40	151	60.72	54.43	21.89	248.7
Sa'ertu	80.85	21.42	218	57.76	78.57	20.82	377.42
Xingshugang	25.62	21.49	68.8	57.72	24.78	20.79	119.2
Gaotaizi	0.33	23.24	0.8	56.34	0.29	20.42	1.42
Taipingtun	1.49	23.24	3.6	56.16	1.32	20.59	6.41
Putao Hua	1.53	15.58	6.1	62.12	2.19	22.30	9.82
Aobaota	0.42	24.14	0.96	55.17	0.36	20.69	1.74
Total	153.51 (92.2Mt)	20.01	449.26 (269.7Mt)	58.75	161.94 (97.2Mt)	21.18	764.71 (458.8Mt)

Assume the volume of formation water is as same as oil, the storage capacity of CO₂ dissolved in formation water is 55-62% of total.

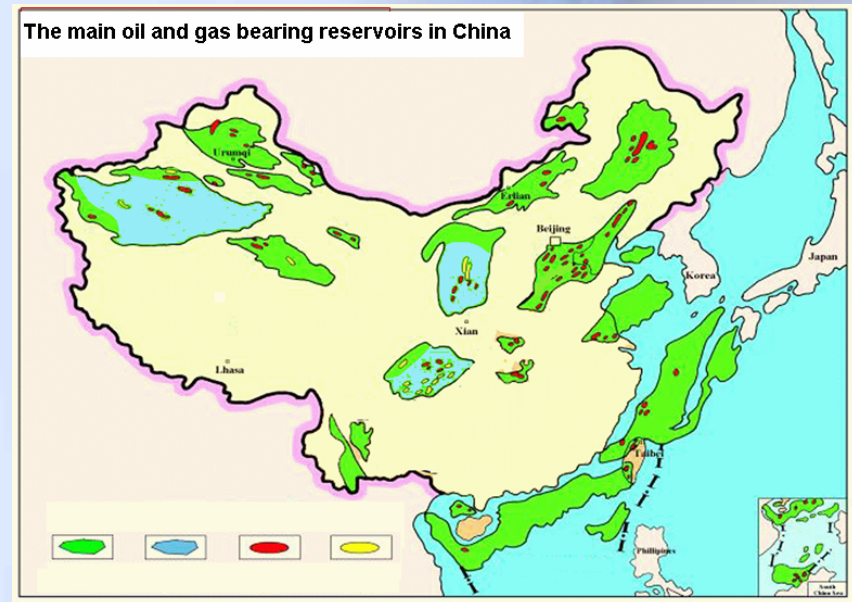
CO₂ EOR + Storage is possible to produce “Green oil”



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

“Green oil” in the future of China

- China has a proved OOIP of low-permeability reservoirs as **6.32 billion tons, which is 28.1%** of the total proven OOIP.
- CO₂ EOR could improve the oil recovery of these reservoirs.
- Most of coal mine close to oil/gas fields. If the CO₂ could be captured from the power stations near the coal mine the source of CO₂ is plenty.



Main oil/gas fields in China

Great potential of CO₂-EOR and storage in China

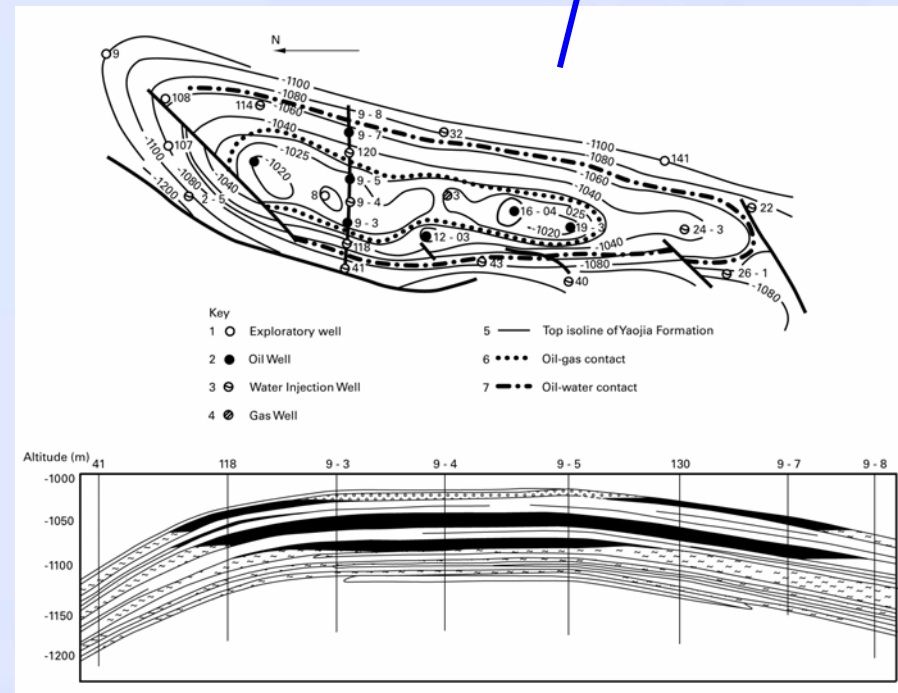
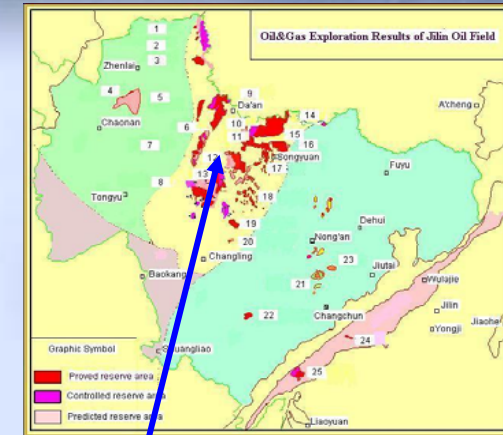


中国石油大学
CHINA UNIVERSITY OF PETROLEUM

Practicable for producing **green oil** ?

Geological characteristics of Honggang oilfield

- Cap gas
- 3 layers of oil
- Formation water
- Data of formation water is available
- Wells are available



It is practicable to produce **green oil** for oil companies



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

Problems to producing **green oil** for oil companies

- **Economics:**

CO₂-EOR, to use CO₂ as less as possible

CO₂-EOR + storage, cost extra money

- **Technology and Engineering:**

Assessment of CO₂ storage potential in water

Wells

Monitoring

Leakage

Environments



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

How oil companies to producing **green oil**?

- **Support from governments**

Governments should develop policy to encourage oil companies implement CO₂-EOR+storage

- **Develop CO₂-EOR+storage technology**

Change the logics of CO₂-EOR or CO₂ storage

Study and solve the problems for developing the low-carbon technology



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

Strategy of CO₂ storage in China

- Deep saline aquifer

Long term development , large volume, no economic interest。

- Depleted oil and gas reservoirs

Long term development, large volume, no economic interest

- CO₂-EOR+storage

Practicable, large volume, can reduce the cost of CO₂ storage,
but cost more than CO₂-EOR

- CO₂-EOR

Practicable , limited volume, can reduce the cost of CO₂ storage

- Enhance coal seam methane

Practicable, limited volume, can reduce the cost of CO₂ storage



中国石油大学
CHINA UNIVERSITY OF PETROLEUM

Conclusion

- China has great potential for **CO₂ EOR + storage** in oil fields
- **CO₂ EOR + storage** could produce “**Green oil**”
- Development of **CO₂ EOR + storage** technology should be promoted in China





Thanks