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Research Institute of Petroleum Exploration & Development, PetroChina.
CNPC Research Institute of Economics and Technology

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Author Biography

- Pingping Shen, Male, Former vice-president of PetroChina ,a senior engineer from Research Institute of Petroleum Exploration & Development, PetroChina, a tutor for Ph.D Candidate, also an expert who is provided special allowance by the government. He worked as a routine executive member of the fourth session council for Chinese Petroleum Society, and now works as the director of Chinese Petroleum Engineering Society.
- E-Mail:spp@petrochina.com.cn
- Publications: 6 monographs, 60 domestic or oversea published papers
- Researching experiences: He has engaged in the research work of EOR for a long time, and has finished several research projects either national or from PetroChina as a manager, which including: Research for enhanced oil recovery. 973 project (The National Basic Research Program) named ‘Basic Research for Enhanced Oil Recovery in A Large Scale’. Potential evaluation for EOR in China oil field and development stratagem. Potential and corresponding plan for tertiary recovery in oil field. He is chief scientist of ”973” project for CCS-EOR.




China Status and Prospects of CO_2 in EOR and Storage

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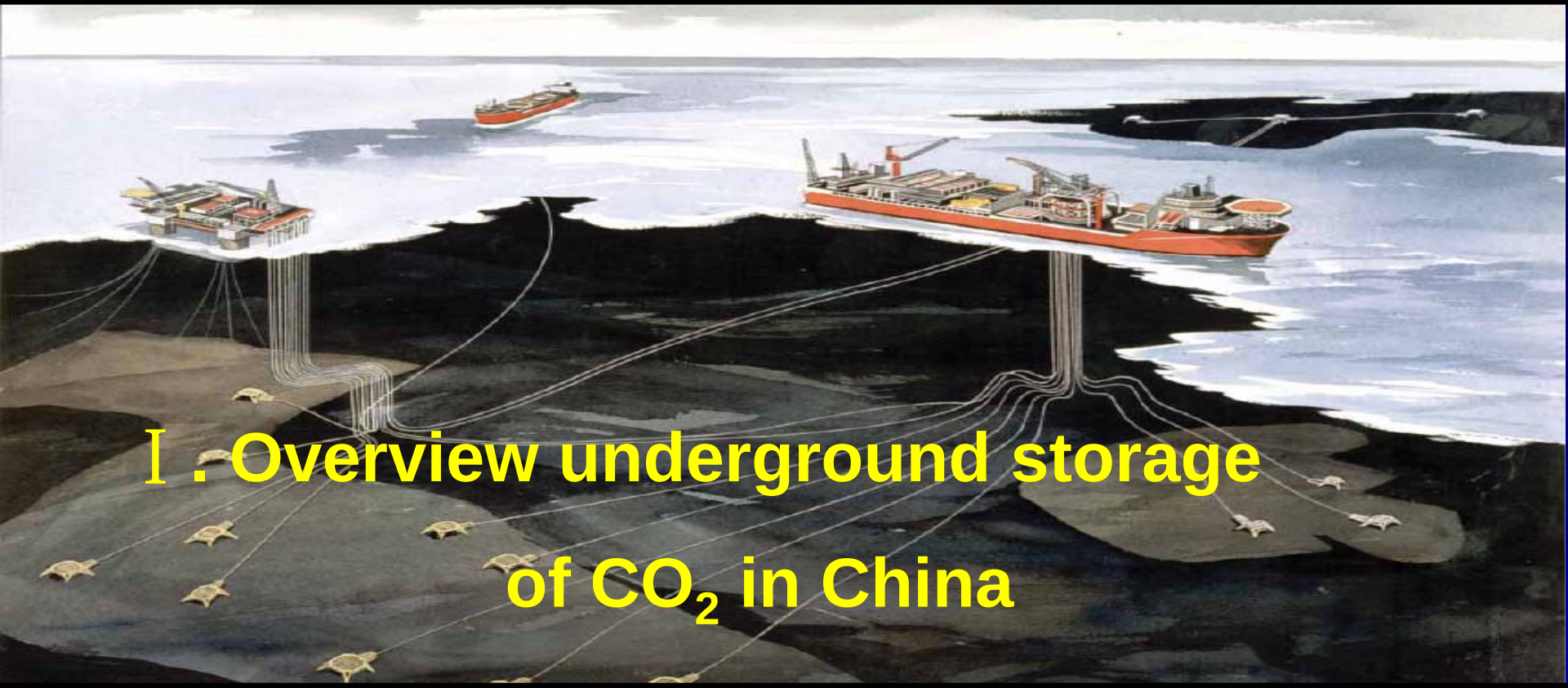
Content



Ⅰ. Overview underground storage of CO_2 in China

（Ⅰ.）CO_2 emissions lead to environmental problems

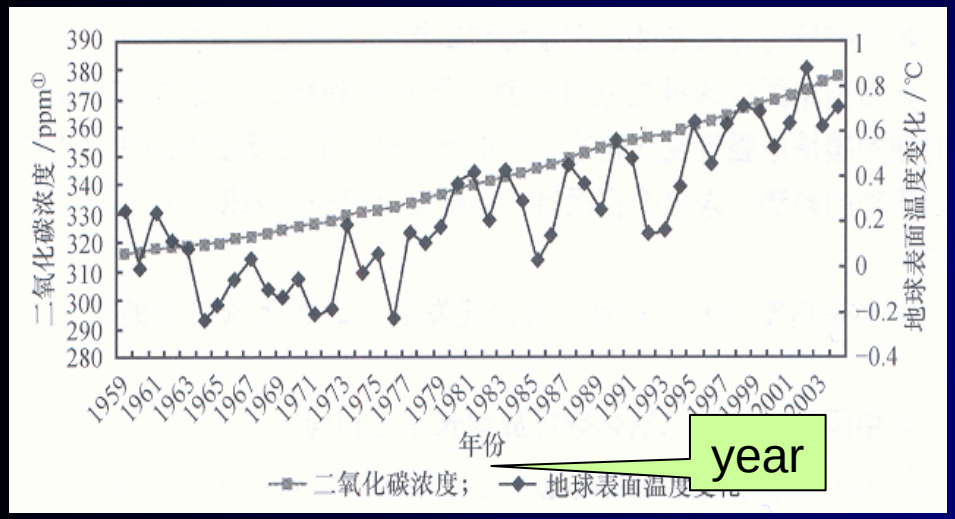


Fig.1 CO_2 concentration and temperature changes in Atmospheric（CDIAC,2005）

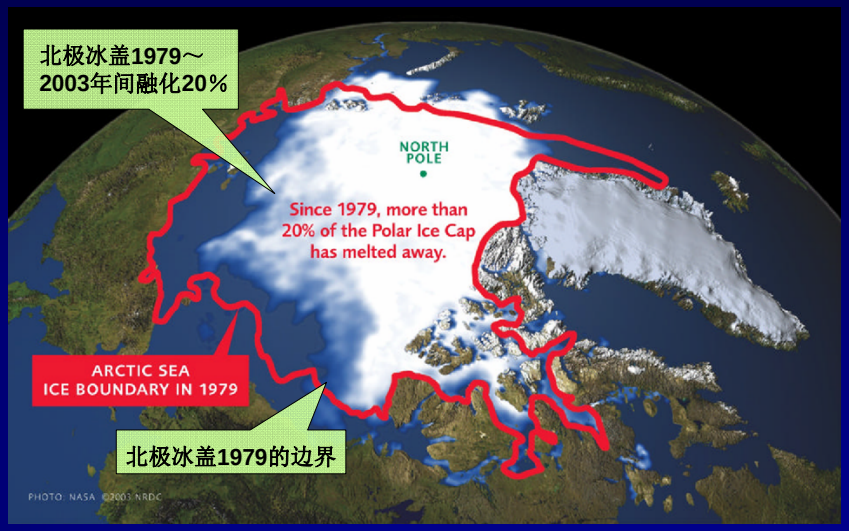


Fig. 2 Arctic ice sheet variation （First CERI Board Meeting October 25, 2004, Golden, CO ）

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（Ⅱ.）Sequestration methods Of CO_2

CO_2 sequestration is an effective way to prevent climate change, CO_2 sequestration must be hundreds or thousands of years. Sequestration must have minimal impact on the environment, low-cost and compliance with national and international laws and regulations.

The main choices of underground deposits :
Depleted oil and gas reservoirs,
Deep saline reservoirs
Coal seam that can not be mined,
Deep-sea sequestration, etc..

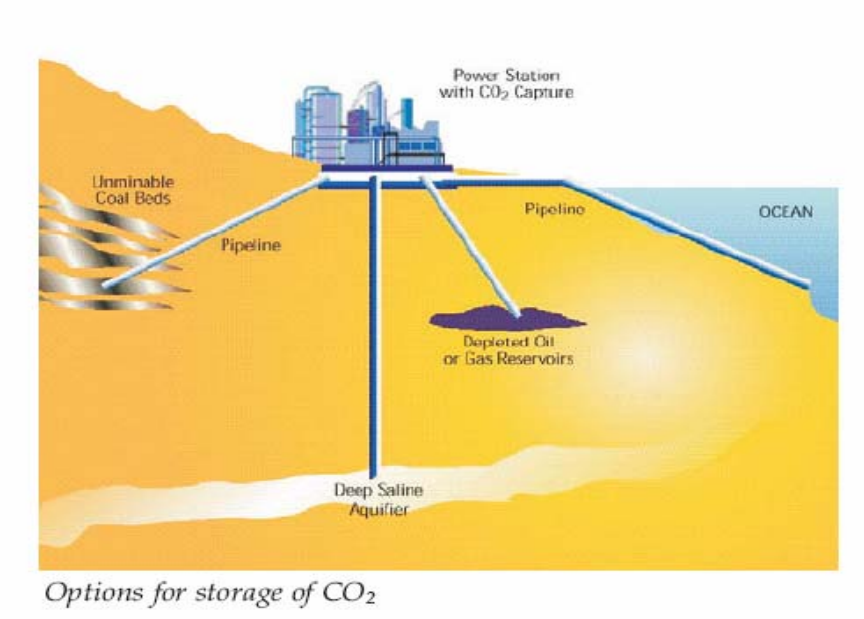


图3 CO_2埋存方式示意图 （IEA，2001）

Some fields can be a place for CO_2 sequestration, depleted oil and gas reservoirs for CO_2 sequestration have the following advantages: Development of low-cost CO_2 sequestration, reservoir proved to be traps, buried oil and gas deposit a few million years, reservoir geological characteristics clear (Fig.4), some of the existing oil and gas production facilities can use the injected CO_2, a number of fields using the conventional methods of oil extraction, injection CO_2 enhanced oil recovery may be 10-15%.

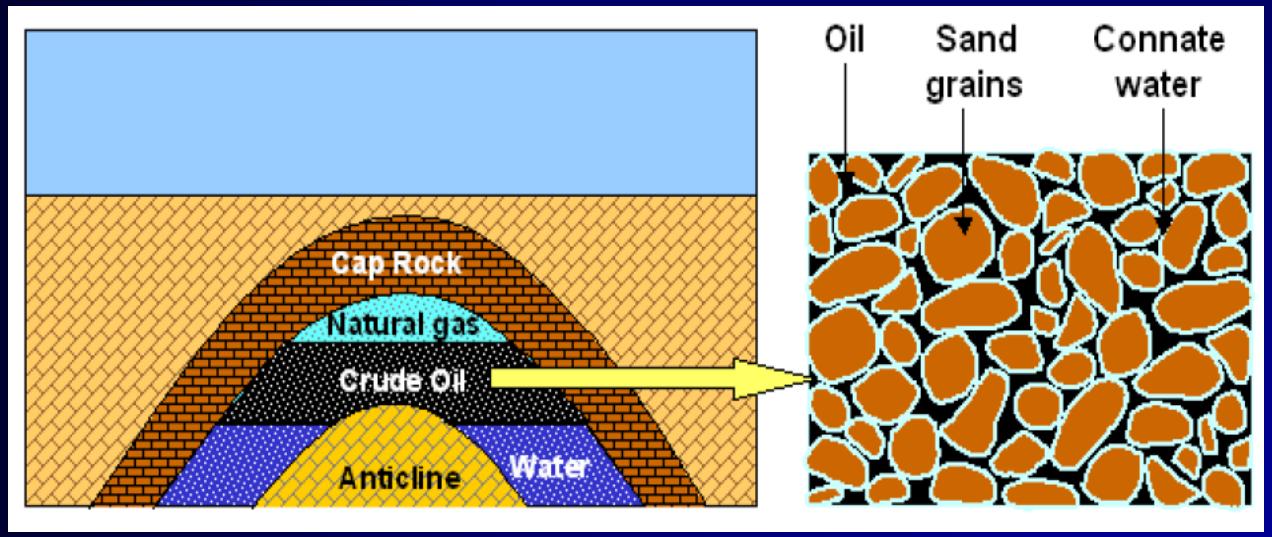
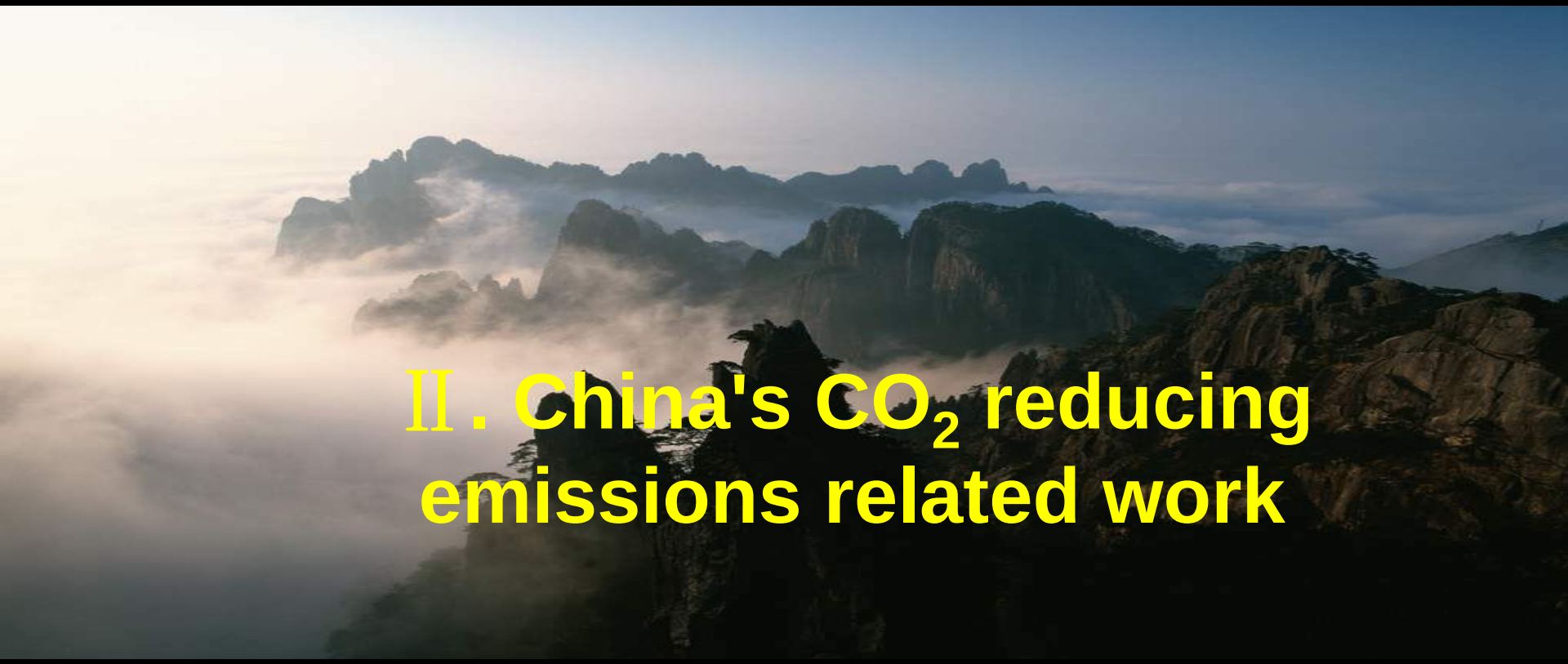


Fig. 4 abandoned oil and gas reservoirs as CO_2 sequestration sites



Ⅱ. China's CO_2 reducing emissions related work

China's solemn commitment as a developing country approved the "Kyoto Protocol." China is a big greenhouse gas emissions country, CO_2emissions is No. 2 in the current world.

China's State Science and Technology in 2006, ratification of "greenhouse gases to enhance oil recovery resource utilization and underground deposits of the" 973 National Key Basic Research Program.

CNPC established a key project “Greenhouse gas CO_2 resource utilization and underground deposits" in 2007.

CNPC established a major field test "an oil CO_2 EOR and underground sequestration field test" in 2007.

III. Research progress of CO_2 in EOR and Storage

（Ⅰ）Establish a suitable CO_2 sequestration evaluation system and the basic geological theory

Make selection characteristics about underground storage and EOR suited to China's criteria geological; deciding on the theoretical potential, effective potential and the additional potential for enhanced oil recovery method of calculating; the establishment of China Basin oil and gas reserves of various databases (including: projected total amount of resources, at present the total amount of resources have been found; forecast recoverable reserves, recoverable reserves have been found).

Preliminary identification of the establishment of China's oil and gas geological model; to China as an example to carry out in an oilfield reservoir description study; conducted aquifer study, CO_2 with different degree of mineralization of water chemical reaction. Two pairs of wells, seismic studies have shown that you can identify the 3-meter-thick reservoir heterogeneity; through research, comprehensive application-hole seismic, vertical seismic, surface seismic and other information that might be applicable to thin, low permeability, gas injection , the leading edge of propulsion research; carried out four kinds of gas tracer studies.

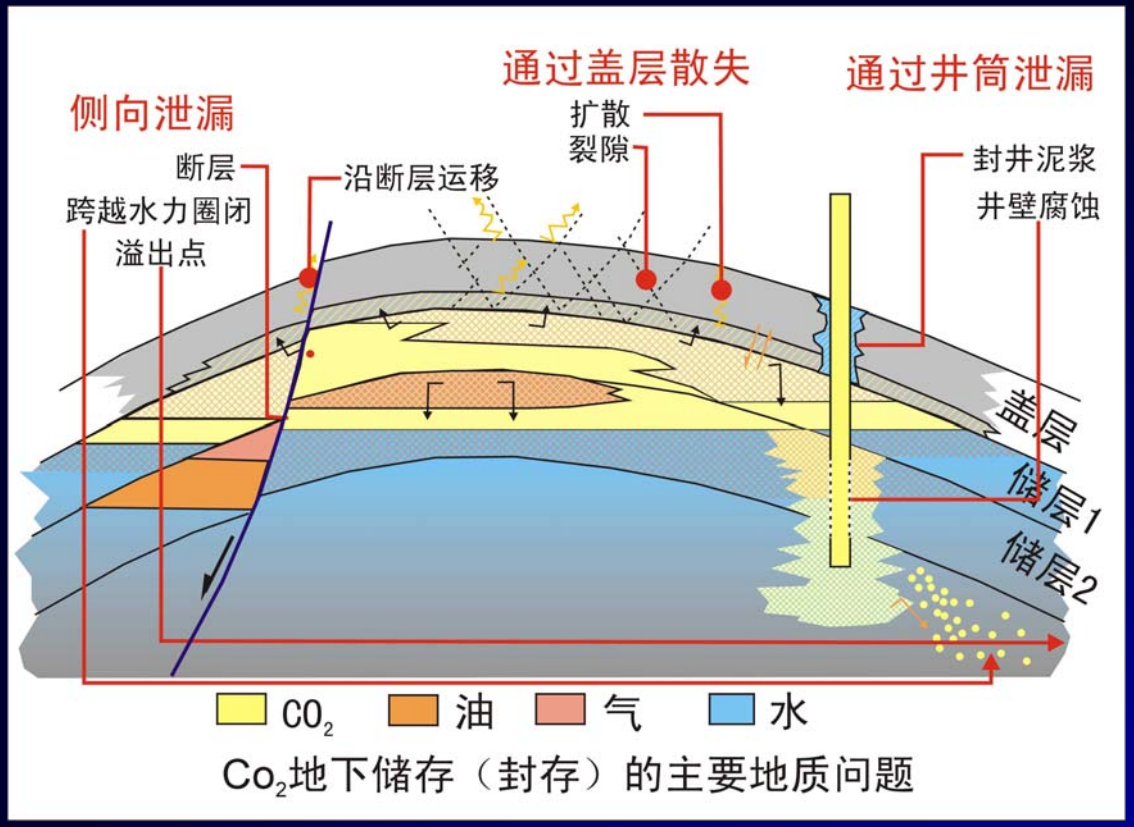


Fig. 5 CO_2 sequestration mechanism of leak

（Ⅱ）Using CO_2 to EOR

Requirements: recovery ratio = swept volume * oil displacement efficiency

Progress: high-temperature high-pressure micro-physical simulation; mixed phase is the main component of C_2-C_5 and its content; studies have shown that rocks the hearts of tube-in-phase state is different from the PVT phase behavior; CO_2 a number of contacts that are evaporation and condensate displacement process.

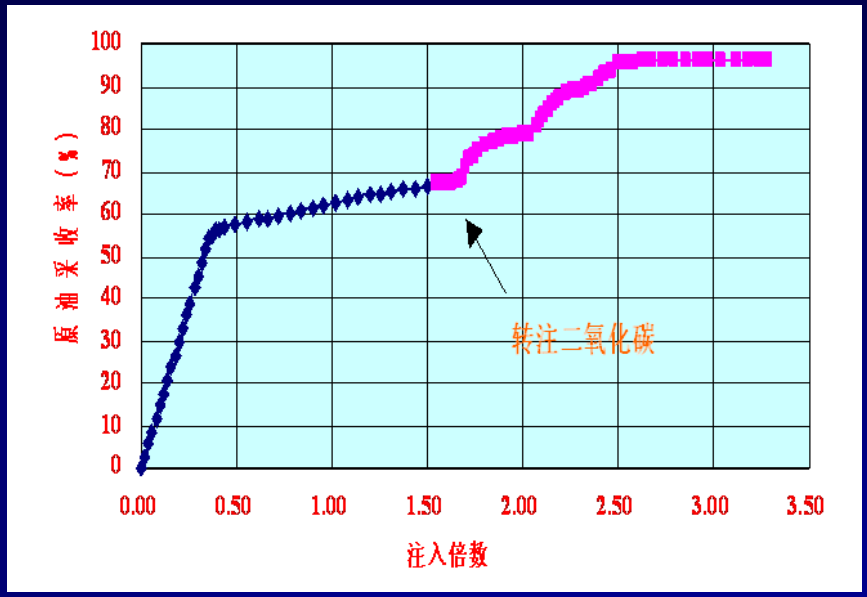


Fig.6 miscible displacement experiments, displacement efficiency up to 97.6%

- **Requirements: Improve the sweep efficiency.**
  Progress: Development of 30 meters high temperature and pressure CO_2 Flooding physical simulation device; to carry out a one-dimensional law of CO_2 seepage studies; undertake a study of the CO_2 flow channeling Road, a block identification and channeling the CO_2-silicate gel deep plugging agent.

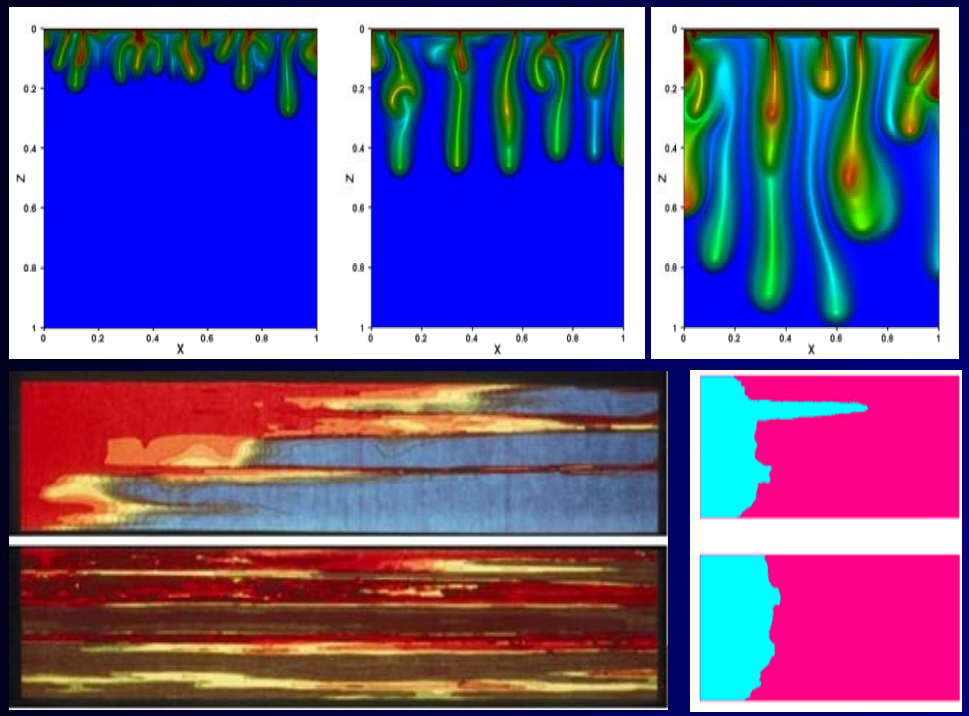


Fig.7 CO_2 Flooding Physical Simulation

（Ⅲ）Effective low-cost CO_2 capture

Requirements: Get low-cost purity of 95% of the CO_2

Progress: Studies of a typical coal of O_2 / CO_2 combustion dynamics, the symbiotic nature of the contaminant; built a pilot-scale test bench.

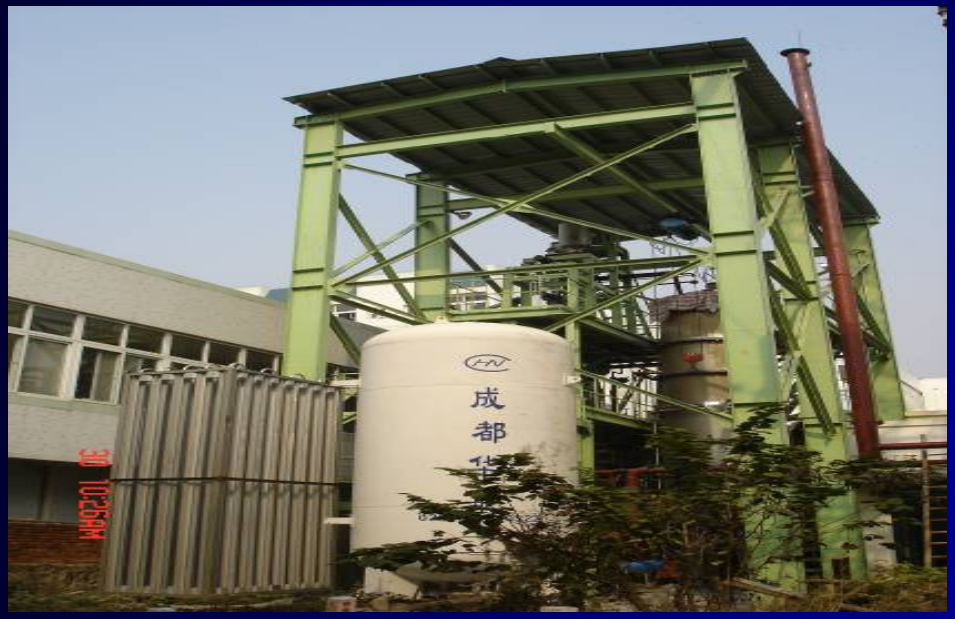


Fig.8 Taiwan's first pilot-scale bed systems

Requirements: From a large number of power plants and industrial gas purification to obtain low-cost CO_2.

Progress: CaO in fluidized bed within the influencing factors; super-critical water in the coal gasification hydrogen production and CO_2 fixation integration factors research; methyl diethanolamine (MDEA) + piperazine (PE); in-depth study containing primary amino (RNH_2) and the Chung-amino (R_2NH) a fixed carrier membrane and CO_2 interaction.

Fig.9 Atmospheric carbon - calcination cycle of test-bed

（Ⅳ）CO_2 Storage and transportation, corrosion and scaling

Requirements: CO_2 buried in the process of reducing the associated engineering costs. Study of safe, efficient storage and transportation techniques and theory; exploration CO_2 corrosion and scaling mechanism and efficient low-cost anti-corrosion, anti-scaling method; CO_2 buried in the process of engineering technology and methods.

Progress: Study on the formation of anti-corrosion systems such as the injection gas anti-corrosion and scaling technology roadmap; CO_2 transport program studied the two kinds of inhibitors, three kinds of CO_2 transport program; determining containing CO_2 gas separation technology; extraction technology presented a set of CO_2 displacement field experiments monitoring methods.

Ⅳ. The storage of CO_2 in Reservoir

A Chinese oil field can be used for CO_2 sequestration in block number 21, its current geological reserves is 119212×10^4t, ultimate recovery of crude oil is 0.2.

Theoretical buried stock calculated as follows:

Sequestration to the theory of free-space underground stock is 24186×10^4t, the theory derived from buried water-soluble stock is 8062×10^4t, the theory derived from crude oil buried dissolved stock is 44632×10^4t, so the total stock of CO_2 theory of buried is 76880×10^4t.

Effectively buried the stock calculated as follows:

Buried in the calculation of effective stock of various factors and effective sequestration coefficients obtained through numerical reservoir simulation. The combined effects of various factors to take effective sequestration coefficient of 0.25, then have been effectively buried the stock of 19220×10^4t.

Analogy method buried stock:

1,reference buried in the stock of foreign literature to determine

CO_2 utilization factor can be divided into three grades: the highest, middle and lowest, their values were collected from 5.0 t/m^3, 3.0 t/m^3 and 1.0 t/m^3,

Recovery rate of increase of CO_2 injected can be obtained by taking the highest, middle and lowest three grades, their values were 0.20, 0.12 and 0.05.

These three levels of the burying of the total stock, respectively 89412×10^{4}t, 32186×10^{4}t, 4470×10^{4}t. Tab.1

From the calculation result, it seems the stock of the highest levels of burying the theory is equivalent to the above calculation to be buried in the stock, effectively buried the stock buried in the middle and the lowest level among the stock.

Tab.1 the results of effectively buried stock calculated with reference to foreign literature

Field	OOIP/10^4t	Max stock/10^4t	Medium stock /10^4t	Min stock/10^4t
A	7332	5499	1980	275
B	341	256	92	13
C	724	543	195	27
D	9808	7356	2648	368
E	19558	14669	5281	733
F	567	425	153	21
G	4549	3412	1228	171
H	2227	1670	601	84
I	106	80	29	4
J	12306	9230	3322	461
K	1105	829	298	41
L	3177	2383	858	119
M	9807	7355	2648	368
N	1502	1127	405	56
O	5838	4379	1576	219
P	12602	9452	3402	473
Q	2021	1516	546	76
合计	93570	70181	25262	3509

Analogy method buried stock:

2、Based on case analysis to determine reservoir buried in the stock

Analysis method by examples of the field 21 oil blocks for the evaluation of the potential buried in the stock, see Tab.2 .
Determine the A-K11 blocks suitable for the use of immiscible CO_2 to enhance oil recovery; L-U10 blocks suitable for the use of CO_2 miscible flooding to enhance oil recovery.

At the same time the light of the oil reservoir numerical simulation of a typical block of H obtained utilization factor of CO_2(1.5935 t/m^3), calculated the total buried stock of 14988×10^4t, the value is equivalent to the above calculation, the effective buried stock (19220×10^4t).

Tab.2 Reservoir Evaluation Based on the results of calculating the effective stock

Immiscible effective sequestration potential of CO_2				Miscible flooding potential for the effective sequestration of CO_2			
Block	OOIP /10^4t	EOR /%	Effective storage /10^4t	Block	OOIP /10^4t	EOR /%	Effective storage /10^4t
A	7332	8.0	701	J	12306	14.0	2059
B	341	7.0	29	K	1105	15.0	198
C	724	8.0	69	L	3177	12.0	457
D	9808	9.0	1055	M	9807	12.0	1406
E	19558	7.0	1636	N	1502	12.0	215
F	567	7.0	47	O	5838	12.0	837
G	4549	8.0	435	P	12602	12.0	1907
H	2227	9.0	240	Q	2021	9.0	217
I	106	8.0	10				

Ⅴ. Conclusions

（1）Greenhouse gas emissions are important issues of concern to the international community.

（2）As a responsible developing country, to take effective measures to carry out the "greenhouse gases to enhance oil recovery resource utilization and underground deposits of the" 973 national key basic research projects.

（3）CNPC to established a key project in 2007 "greenhouse gases, CO_2 enhanced oil recovery and underground sequestration," a major field test, "an oil field to improve oil recovery and underground CO_2 sequestration field test."

（4）Greenhouse gas to EOR resource utilization and underground deposits of research according to the work plan forward, and made important progress.

（5）The Chinese government actively participates in international cooperation to achieve greenhouse gas to EOR resource utilization and underground deposits is bound to the high level of global resources and the environment, cost-effective to develop and make a positive contribution to sustainable development.

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