Natural Gas Geological Theory and Testing Technology

Science & Technology Management Department

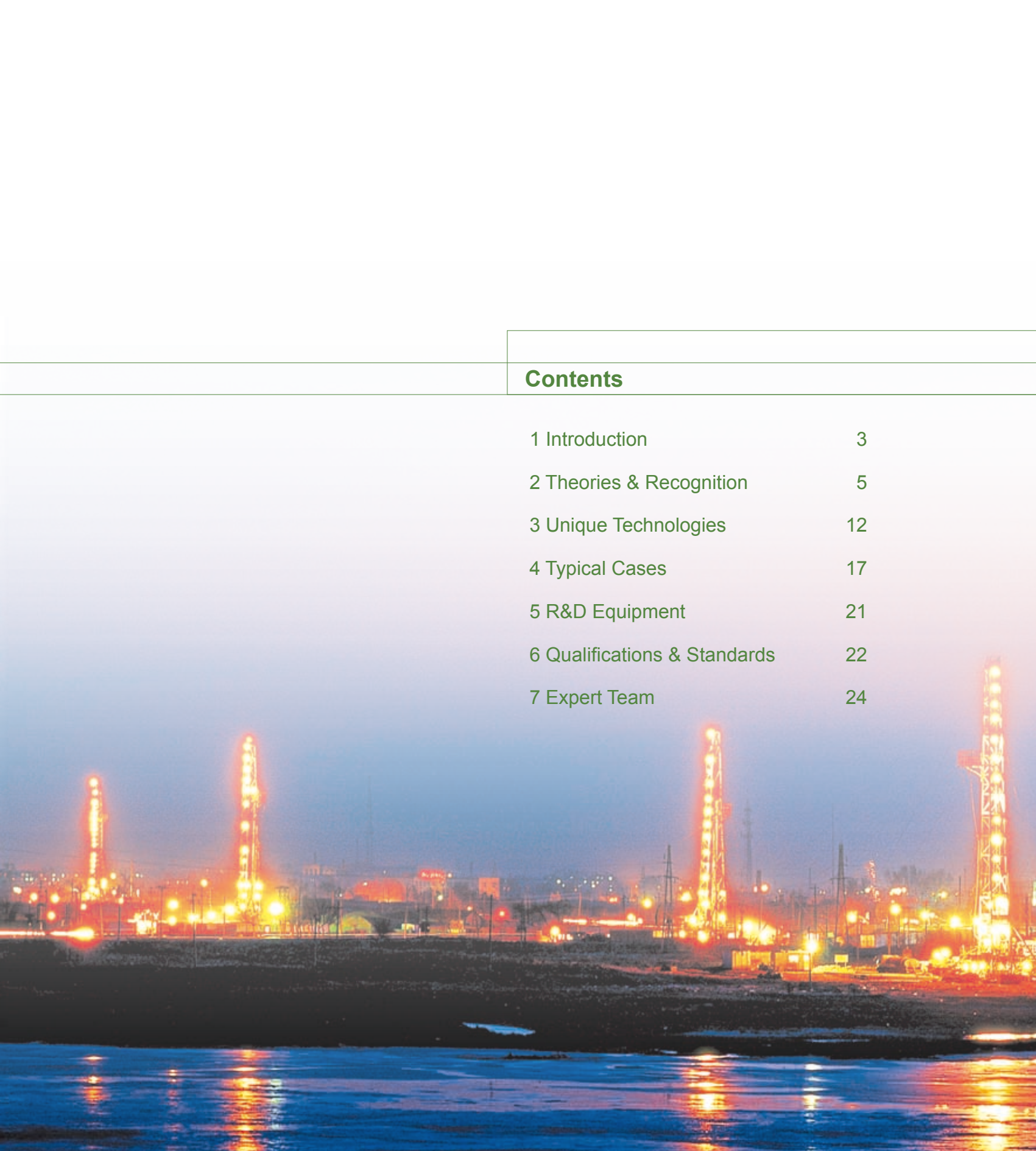
2013

CHINA NATIONAL PETROLEUM CORPORATION

Develop natural gas geological theory

Improve natural gas exploration level !

Contents



China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorgnized to become an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integrations of upstream and downstream operations, internal and external trade, production and marketing. CNPC's business covers six main sectors: oil and gas operations, petroleum engineering service, petroleum engineering construction, petroleum equipment manufacturing, financial services and new energy development. In 2012 CNPC produced 110 million tons of crude oil and 79.82 billion cubic meters of natural gas, while crude processing volume reached 191 million tons. The total revenue of RMB 2,690 billion with a profit of RMB139.1 billion had been achieved the same year.

CNPC was ranked 4th among the world's largest 50 oil companies and 6th in Fortune Global 500 in 2012.

CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed on the solutions of key bottleneck technologies and key proprietary technologies. Thanks to continuously improving of the technical innovation system, optimizing the configuration of technological resources and strengthening the construction of strong talent teams, CNPC's technological creativity has been considerably upgraded. Consequently, a large number of technologies have been developed independently, with its own intellectual property.

Natural Gas Geological Theory and Testing Technology is one of representatives for major innovations of CNPC.

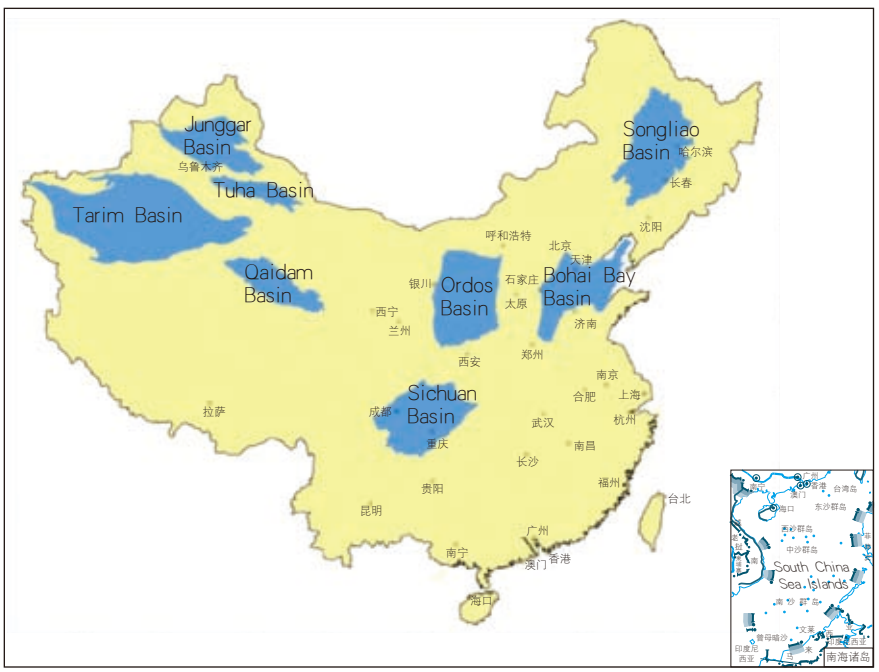
CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

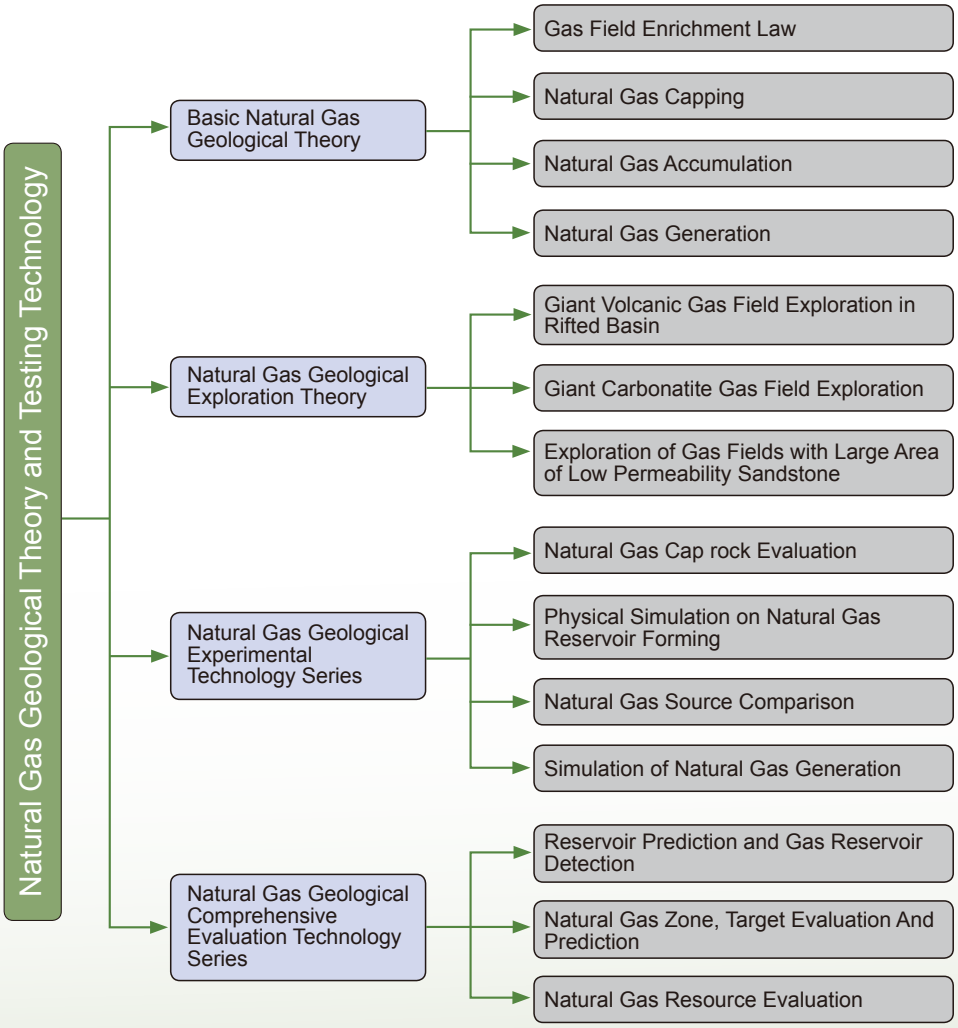
1 INTRODUCTION

As the energy consumption worldwide became more and more low carbon-oriented, the proportion of natural gas in the primary energy consumption has been expanding. The geological theory and testing technology serve as the important base and means for natural gas exploration, and are the guarantee for the succession of natural gas resource and fast and steady growth of natural gas reserves and output.

CNPC has been long devoted to the research and practice of natural gas geological theory and testing technology and has developed basic natural gas theory, natural gas geological exploration theory, natural gas geological experimental technology and natural gas geological comprehensive evaluation technology. With its dominant technology advantages and broad service fields, it is able to meet the international advanced level as a whole.

The natural gas geological theory and testing technology have been successfully applied into explorations in Sichuan, Erdos, Tarim, Qaidam, Dzungaria, Songliao, Tuha, Bohai Bay and other gas fields, providing a solution for succession of natural gas reserves and ensuring the fast growth of natural gas reserves and output, as well as providing theory and technology guarantee for projects in peek period of CNPC's oil reserves.




Natural Gas Geological Theory and Testing Technology
Basic Natural Gas Geological Theory
Gas Field Enrichment Law
Natural Gas Capping
Natural Gas Accumulation
Natural Gas Generation
Natural Gas Geological Exploration Theory
Giant Volcanic Gas Field Exploration in Rifted Basin
Giant Carbonatite Gas Field Exploration
Exploration of Gas Fields with Large Area of Low Permeability Sandstone
Natural Gas Geological Experimental Technology Series
Natural Gas Cap rock Evaluation
Physical Simulation on Natural Gas Reservoir Forming
Natural Gas Source Comparison
Simulation of Natural Gas Generation
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Reservoir Prediction and Gas Reservoir Detection
Natural Gas Zone, Target Evaluation And Prediction
Natural Gas Resource Evaluation

2 THEORIES & RECOGNITION

Natural gas is characterized by simple molecular structure, small molecular weight, small molecular radium, small viscosity and easy diffusion. This determines the basic natural gas geological theory is different from that of oil.

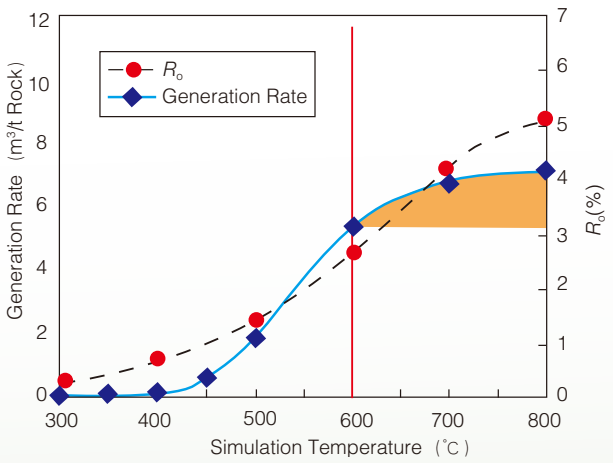
CNPC has a professional institute for the research of natural gas exploration, which is the only one of a kind in China. With many years of efforts, big progress has been made in exploring natural gas generation, accumulation, capping, reservoir forming mechanism of large gas fields and enrichment laws, which has greatly boosted the natural gas exploration and discovery of giant gas fields.

2.1 Natural Gas Generation

A great breakthrough has been made in the research of lower limit for the generation of coal-derived gas, crude oil cracking gas and biogas, based on which, the natural gas generation theory is developed.

Coal-derived Gas

The experiments show that due to the particular structure of coal bed source rocks, the coal and carbonaceous mudstone are still able to generate more than 20% natural gas during the post mature phase, and thus the lower limit of gas generation is extended from R_o=2.5% to 5.0%. The amount of coal-derived gas is raised by approx. 1/4 over the past.



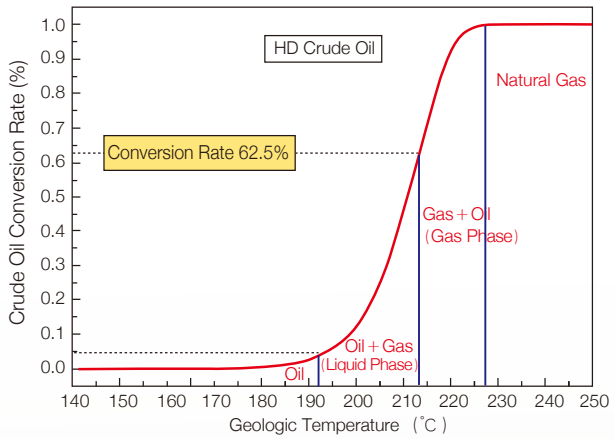
Gas Generation Rate Model of Coal

Crude Oil Cracking Gas

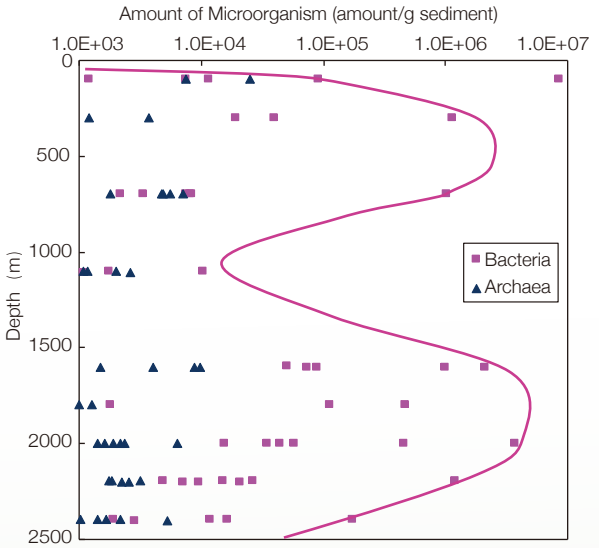
Kinetics simulation experiments on hydrocarbon generation show that the geologic temperature for the termination of crude oil cracking is 230℃, instead of 200℃ in the past. This provides theoretical basis for predicting crude oil cracking gas.

Biogas

It is generally believed that 75 ℃ is the lower limit for the generation of biogas and exploration, however, according to the simulation experiments, there is still a large quantity of bio-methane generated at 85 ℃. Therefore, the biogas generation depth and exploration lower limit will be further extended downward.



The Relationship between Crude Oil Conversion Rate and Geologic Temperature



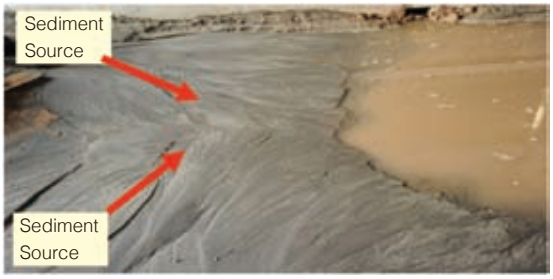
Microbial Population Detected at Different Depths

2.2 Natural Gas Accumulation

New progress has been made in exploring the genesis of widespread sand bodies and formation of deep clastic rocks, etc.

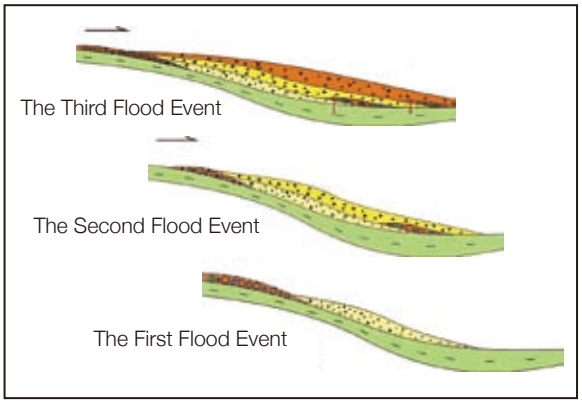
Genesis of Widespread Sand Bodies

Widespread sand bodies were formed under the background of gentle structure, multiple species sources and frequent vibration of water bodies.

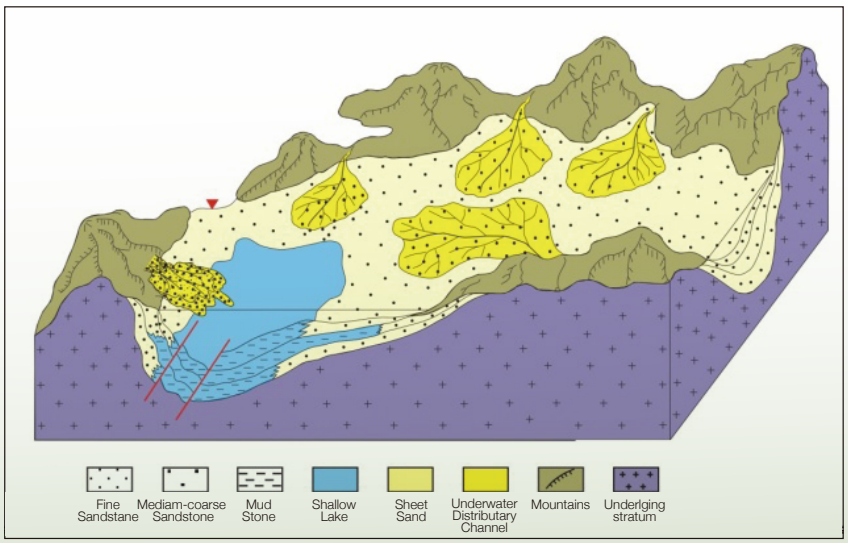


Multiple-source Flume Physical Experiment

Sedimentation model



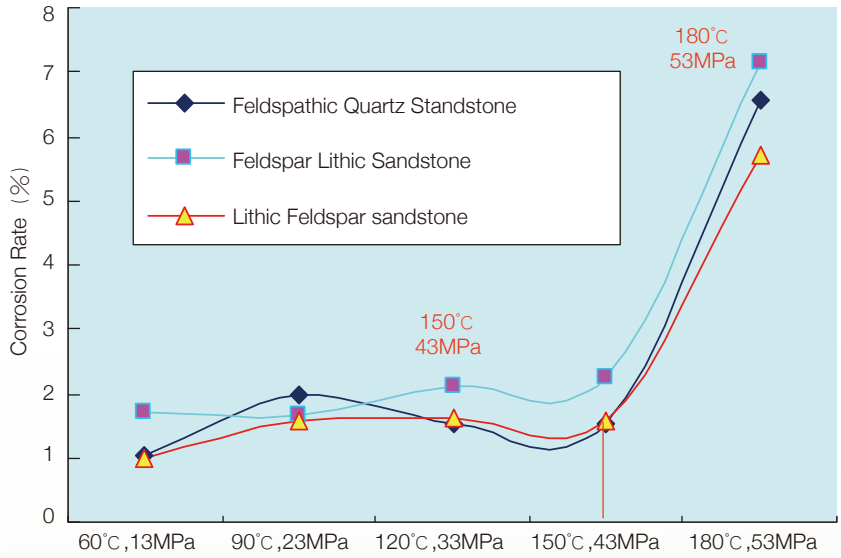
Sedimentation Model of “Flood Events”



“Flow Pattern” Sedimentation Mode

Deep Clastic Rock Reservoir

The corrosion experiment under high temperature and high pressure shows that the corrosion rate of feldspar and other soluble components increased 2-3 times under high temperature and high pressure, and this will greatly improve the accumulation capacity of the deep part of the reservoir.



Corrosion Rate of Sandstone under Different Temperature and Pressure

2.3 Natural Gas Capping

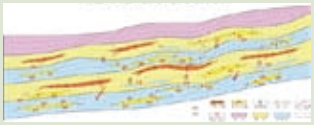
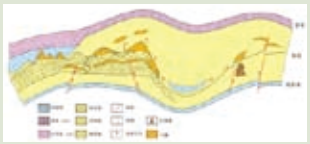
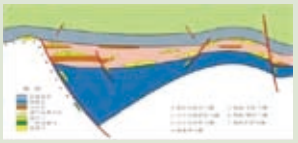
The sealing mechanism of cap rocks mainly includes the capillary sealing, overpressure sealing, hydrocarbon concentration sealing and succession sealing, etc. The sealing capacity of cap rocks of natural gas reservoir was evaluated by qualitative evaluation of cap rock macro parameters or quantitative evaluation of micro parameters in the past. At present, it is evaluated by comprehensive quantitative evaluation combining macro parameters and micro parameters.

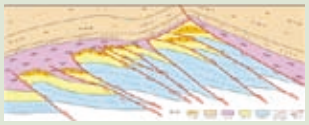
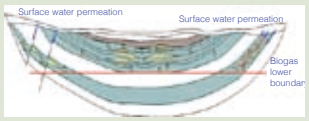
Quantitative Evaluation Method for the Sealing Capability of Cap Rocks

A comprehensive quantitative evaluation method is developed based on the consideration of cap rock thickness, displacement pressure, gas reservoir pressure coefficient and faults; different quantitative evaluation parameter systems are established for different cap rocks of gas fields, and gas sealing capacity of cap rocks in different giant gas fields are evaluated.

2.4 Enrichment Law in Giant Gas Fields

New progress was made in exploring gas reservoir forming mechanism in giant gas fields with low-permeability sandstone, carbonate reef flats and karst, volcanic rocks in rifted basins and super-pressure and biogas fields as well as main controlling factors and enrichment law. This will greatly enrich and complete the reservoir forming theory for giant gas fields.

Gas Reservoir Type	Reservoir Forming Pattern	Reservoir Forming Mechanism	Typical Examples	Main Controlling Factors	Distribution
Low permeability sandstone gas reservoir		Overpressure of hydrocarbon generated from source rocks; migration of non-Darcy flow; dynamic trap formed near the source	Source-reservoir alternating (Xujiahe Fm.); Source-reserve overlapping (He 8-Shan 1 in Sulige)	Large delta sedimentary system; large area of overlapping of source and reservoir	Mainly distributed in advantageous source-reservoir overlapping area of large delta sedimentary system
Carbonate gas reservoir		Mixture of multiple sources; multi-phase charging; crude oil cracking; gas cut restructuring	Gas reservoir in reef flat of platform margin; karst weathered crust gas reservoir; gas reservoir in inter-platform reef flats; gas reservoir in bedded dolomites	Platform margin belt and weathered crust; transporting system	Mainly distributed in of platform margin reef flat in marine basin and palaeohigh and development area of karst reservoir on slopes
Volcanic gas reservoir		Concentrated near the source; enrichment around the trough	Gas reservoir with gas transported through faults (deep layer of Songliao); gas reservoir with gas transported through faults and unconformities (Kalameili)	Lithofacies, lithology; transporting system	Mainly distributed in superior reservoirs of explosive and overflow facies, which are communicated through faults

Gas Reservoir Type	Reservoir Forming Pattern	Reservoir Forming Mechanism	Typical Examples	Main Controlling Factors	Distribution
Super-pressure gas reservoir		Rapid and powerful charging; ultra-late reservoir forming; ultra-strong capping	Structural gas reservoir (KL 2, DB1, etc.)	Fast and strong charging of source rocks; ultra-strong capping of gypsum rocks	Mainly distributed under superior cap rocks such as gypsum rocks and mud rocks and structures or compound structures with faults.
Biogas reservoir		Self-generated, self-reserved; migration vertically near the source; growth fault trap-controlled reservoir; successive sealing	Primary biogas reservoir (SB1, etc); Secondary biogenic gas reservoir (shallower layer in Songliao)	Continual gas-generating of large amounts of soluble organic materials; successive seal-ing of mudstone	Mainly distributed in shallow source-abundant areas with good preserving conditions

2.5 Natural Gas Geological Exploration Theory

The theory for exploring giant gas fields with large area low permeability sandstone, carbonate karst and platform margin reef flats and volcanic rocks in rifted basins, etc., has been formed and developed, which provides guidance upon the exploration of different giant gas fields.

- Exploration of Giant Gas Fields with Large Area Low Permeability Sandstone;
- Exploration of Giant Gas Fields with Ancient Carbonate Karst;
- Exploration of Giant Gas Fields in Reef Flats of Carbonate Platform Margin;
- Exploration of Giant Gas Fields in Rifted Basins with Volcanic Rocks.

3 UNIQUE TECHNOLOGIES

3.1 Nature Gas Geological Experimental Technology

With the internationally-advanced key lab for natural gas reservoir forming and development, the CNPC is in possession of a series of domestically-advanced technologies in natural gas geology and development experiments, of which, the special technologies for natural gas geology experiments include natural gas generation simulation technology, natural gas genesis identification and gas source comparison technology, natural gas reservoir forming physical simulation technology and natural gas cap rock evaluation technology.

Simulation on Natural Gas Generation

With the availability of the whole series of natural gas generation simulation technologies, which are applied in open, closed, semi-open or semi-closed system, the staff are able to simulate the generation of biogas, kerogen cracking gas and crude oil cracking gas under different geological conditions. These technologies are mainly applied to study the generation mechanism of natural gas and establishment of gas generation models.

Technology Name	Technical Features	Experiment System
Technology for whole rock successive and no loss natural gas generation simulation	On-line simulation testing, successive and no loss, small amount of samples, max. pressure 900℃ (corresponding R_o is above 5%), able to reflect the hydrocarbon generation and expulsion process.	Open
Technology for hydrocarbon generation simulation under high temperature and high pressure	Temperature programming, max. temperature 600 ℃ , max. pressure 60MPa, appropriate for simulation of large amount of samples.	Closed
Technology for MSSV hydrocarbon generation simulation	Able to realize multiple temperature programming, kinetics simulation on hydrocarbon generation, support 27 sets of experiments simultaneously, max. temperature 600℃ .	
Technology for kinetics simulation on hydrocarbon generation	Temperature programming, pressure up to 80MPa, kinetics simulation on isotopes, support 16 sets of experiments simultaneously, max. temperature 800℃ .	
Technology for hydrocarbon generation simulation under formation conditions	Simulation temperature up to 700℃ , max. static pressure of overburden rocks 200MPa, max. fluid pressure 120MPa, able to simulate the hydrocarbon generation and expulsion process under formation conditions to greatest extent.	Semi-closed—semi-open, closed
Technology for biogas generation simulation	Multi-stain, multi-temperature, support 20 sets of experiments simultaneously.	

Natural Gas Genesis Identification and Gas Source Comparison

10 special technologies are developed for identification of genesis of natural gas and gas source comparison.

Technology Name	Technical Features
Natural gas composition analysis technology	Analyze C_1-C_5, H_2, N_2, O_2, CO_2, H_2S and Hg in natural gas, source rock simulation gas, and gas component of bulk fluid inclusions on line
Technology for analyzing carbon isotopic composition of natural gas	In addition to natural gas, analyze carbon isotope composition of source rock simulation gas and gas component of bulk fluid inclusions on line
Technology for analyzing hydrogen isotopic composition of natural gas	In addition to natural gas, analyze hydrogen isotope composition of source rock simulation gas and gas component of bulk fluid inclusions on line
Technology for analyzing light hydrocarbon	Analyze natural gas, on-line source rock simulation gas and crude oil C_5-C_8 light hydrocarbon composition
Technology for analyzing carbon isotopic of light hydrocarbons in natural gas	Analyze natural gas, on-line source rock simulation gas and C_5-C_8 light hydrocarbon carbon isotope composition
Technology for analyzing hydrogen isotopic of light hydrocarbons in natural gas	Analyze natural gas, on-line source rock simulation gas and C_5-C_8 light hydrocarbon hydrogen isotope composition
Biomarkers of natural gas	Enrich natural gas and analyze composition of biomarkers of sterane and terpane
Technology for comparing natural gas isotope kinetics	Analyze carbon and hydrogen isotope composition of natural gas and source rock simulation gas, establish dynamics models for carbon and hydrogen
Technology for comparing composition of rare gases and isotopes	Separate and quantify noble gases such as He, Ne, Ar, Kr and Xe in natural gas, source rocks, inclusions, crude oil and formation water
Technology for analyzing composition of non-hydrocarbon gases and isotopes	Analyze composition of non-hydrogen gases and isotopes on line (CO_2 carbon-oxygen, H_2S Sulfur, N_2 nitrogen), easily operable

Physical Simulation on Natural Gas Reservoir forming

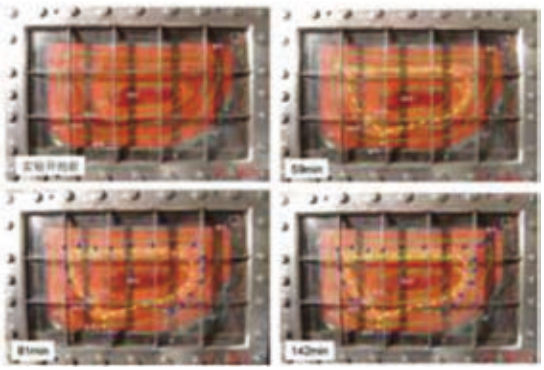
The most complete 1D, 2D and 3D physical simulation systems were developed domestically for reservoir forming of natural gas. These systems are able to test the whole diameter, length, high temperature, high pressure and saturation on line, and to create 3D image slices.

Simulation on natural gas migration and charging

It is used to simulate the fractionation characteristics of natural gas during migration and study the charging power of low permeability sandstone and reservoir forming mechanism.

2D visual physical simulation on natural gas reservoir forming

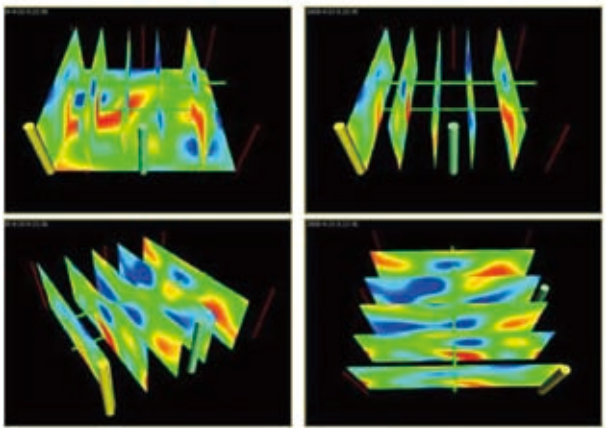
It is used to simulate the physical process of migration and accumulation of natural gas in horizontal and vertical directions.



2D reservoir forming simulation experiment

3D dynamic physical simulation on natural gas reservoir forming

It is used to simulate the accumulation process of gases in different types of traps and to predict the favorable distribution areas of gas reservoirs.



One or several cross sections with different temperature and pressure may be chosen at random

Natural Gas Cap Rock Evaluation

Natural gas cap rock evaluation technologies include technologies for analyzing breakthrough pressure, pore permeability, cellular structure, specific surface area and diffusion coefficient, etc.

Technology for measuring the breakthrough pressure of cap rocks under formation conditions

By using the direct replacement method, it is possible to measure the breakthrough pressure of different types of cap rocks under simulated formation conditions, applicable to rock samples in entire length and with different sizes.

Technology for measuring the diffusion coefficient under high temperature and pressure

By breaking the tradition of conducting measurement under normal temperature and pressure, this technology allows for measurement of diffusion coefficient of rocks under high temperature and pressure (maximum temperature 150℃ , maximum pressure 70MPa).

Technology for analyzing specific surface of rocks

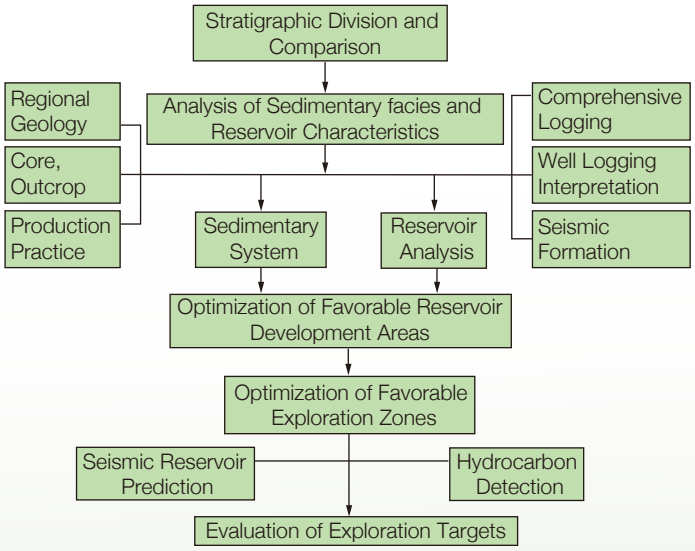
The static quantitative method adopting isothermal temperature physical adsorption allows for analysis of single point, multiple point specific surface areas and pore sizes, etc., more approximate to geological conditions than the past dynamic adsorption method.

3.2 Technology for Comprehensive Evaluation of Natural Gas Geology

Zone and Target Evaluation

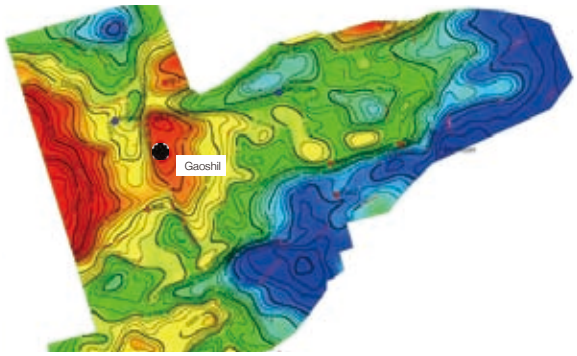
Zone Evaluation

Based on the analysis of geological conditions for reservoir forming, major controlling factors are comprehensively considered to divide the exploration areas into different exploration zones to evaluate their potential.



Target Evaluation

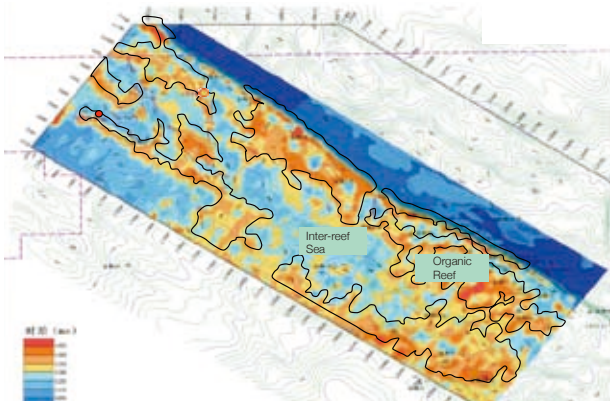
Within the key exploration zones, seismic data shall be used to interpret and evaluate the traps and optimize exploration targets. The well location may be decided based on reservoir prediction and gas-bearing formation detection results.



Reservoir Prediction and Gas-bearing Formation Detection

Reservoir Prediction

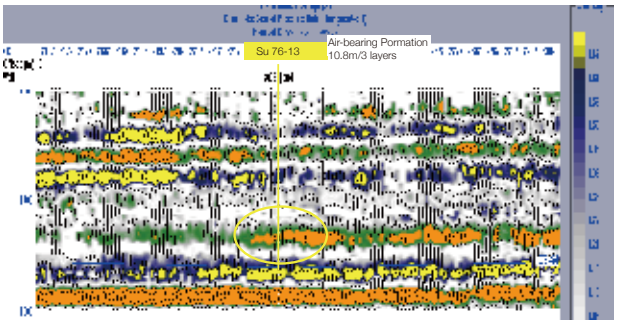
The seismic reservoir prediction method is established for low permeability sandstone, carbonate karst, reef flats and volcanic rocks to predict favorable reservoir distribution and guide the selection of well locations.



To identify the development and distribution of organic reef reservoir based on seismic facies

Gas-Bearing Formation Detection

Specific methods are established for analyzing AVO, seismic inversion (wave impedance and seismic attribute inversion) and multiple-attributes.

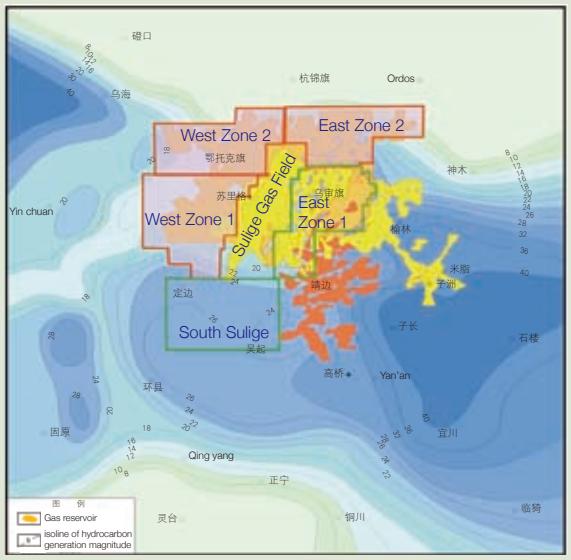


To analyze gas-bearing content based on seismic attribute analysis

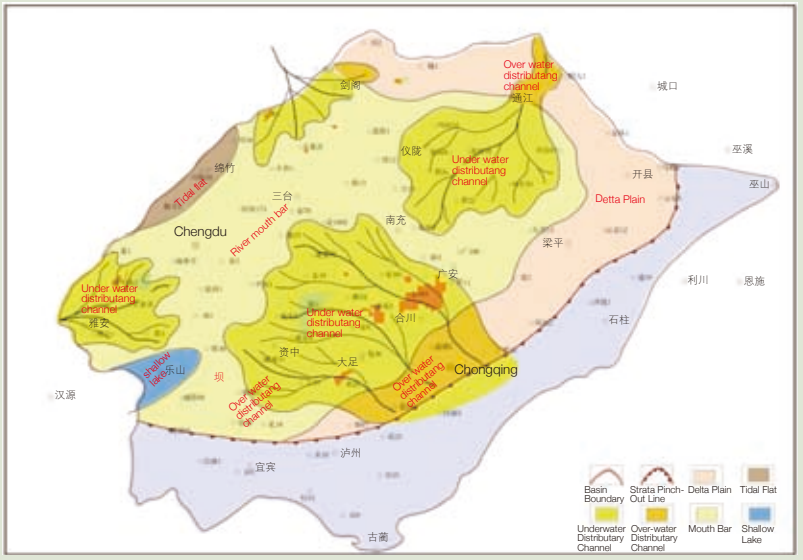
4 TYPICAL CASES

4.1 Application of Exploration Theory of Giant Gas Fields with Low Permeability Sandstone

The core of the exploration theory of giant gas fields with low permeability sandstone is that the accumulation is near the source and the accumulation efficiency of low abundance reservoir is high. Areas with gas generating strength up to 1 billion m^3/km^2 may form into giant gas fields, challenging the opinion of 2 billion m^3/km^2 in the past, expanding the exploration areas for giant gas fields, and effectively guiding the westward and northward expansion of Sugeli gas field in Ordos Basin, and the expansion of Xujiahe Fm in Sichuan Basin.



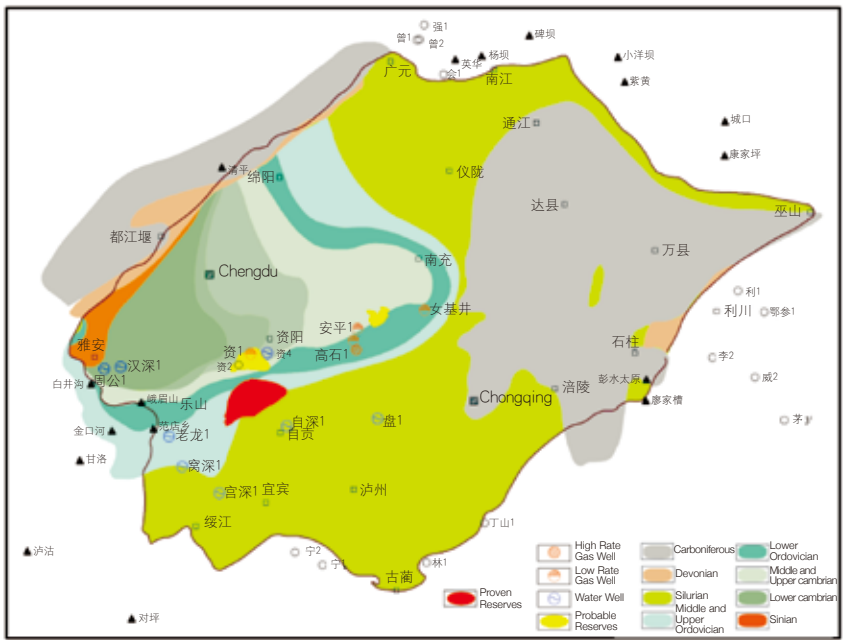
Gas Generating Strength of Upper Palaeozoic Hydrocarbon Source Rocks and Gas Fields Distribution in Ordos Basin



Sedimentary Facies of Xujiahe FM and Distribution of Gas Fields in Sichuan Basin

4.2 Application of Exploration Theory of Giant Gas Fields with Ancient Carbonate Karst

The core of the exploration theory of giant ancient carbonate karst gas field is to seek for high positions in large ancient hydrocarbon source rocks, large ancient reef-bank karst reservoirs, crude oil cracking areas in large ancient oil reservoirs and inherited paleo-uplifts. This theory provided effective guidance upon the arrangement of Gaoshi 1 well, and led to the discovery and evaluation of Gaoshiti-Moxi Sinian-Lower Palaeozoic giant gas field as well as powerfully supported the construction of an industrial base for 30 billion m^3 natural gas in Sichuan Basin.

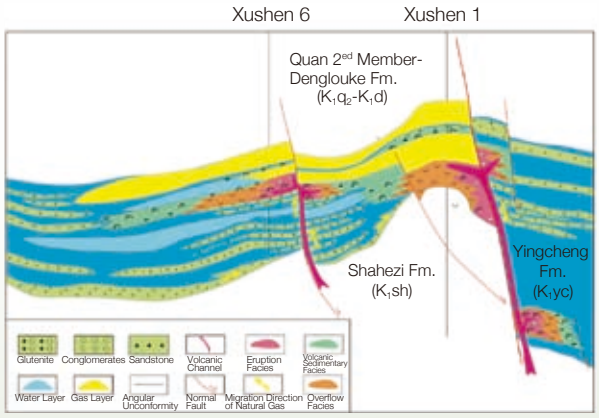


Paleogeologic Map of Sichuan Basin before Permian Sedimentation

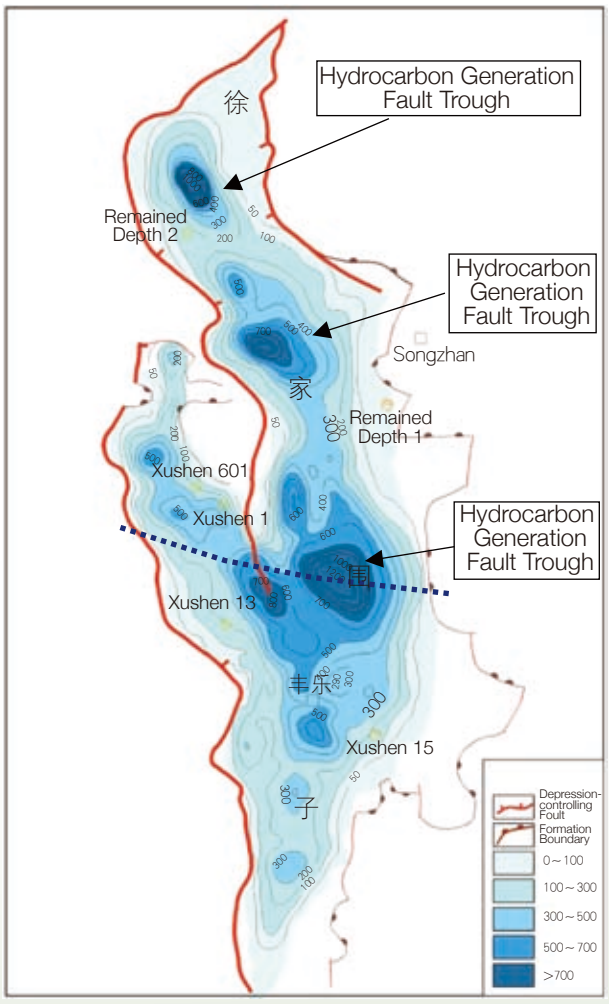
4.3 Application of Exploration Theory of Volcanic Gas Fields in Faulted Basins

The bottom of Songliao Basin is a fault basin group consists of 36 independent faults, with each fault consisting of one or more secondary fault troughs, which control the development of hydrocarbon source rocks and form a gas bearing system alone. The exploration theory of volcanic gas fields in Faulted basins is changed from “seeking for large lake basins and large faults” to “seeking for major hydrocarbon generating fault troughs”. This theory leads to the exploration for middle and small-sized faults.

22 faults in the deep layer of Songliao Basin were evaluated and 11 favorable faults were preferentially chosen. The actual exploration in Xujiaweizi, Changling, Gudian, Wangfu and other places proved that the success rate of exploration wells in small and middle-sized faults is up to 100%.



Profile of Xushen 1 Gas Reservoir, Xujiaweizi Faulted sag



Distribution Map of Hydrocarbon Generation Fault Trough of Xujiaweizi Faulted sag

4.4 Application of Natural Gas Source Comparison Technology in Exploration

The identification of genesis of natural gas and gas source comparison are meticulously carried out for Sichuan, Erdos, Tarim, Dzungaria Songliao and other major gas zones by applying the special “natural gas genesis identification and gas source comparison technology”, which have been playing a significant role in studying the natural gas reservoir forming and making exploration decisions.

Sichuan Basin

Based on technical analysis upon the composition, carbon isotope and rare gas isotope of natural gas and that of simulated gas from source rocks, it is concluded that Sinian natural gas is the crude oil cracking gas which is closely associated with Sinian source rocks. This conclusion confirmed the big contribution of Sinian source rocks to the formation of giant gas fields, and promote the development of the ancient carbonate reservoir forming theory, as well as provided effective guidance upon the evaluation and exploration of natural gas in Gaoshiti--Moxi area.

Ordos Basin

Based on technical analysis upon the composition, light hydrocarbon, carbon isotope, isotope dynamics of natural gas and that of simulated gas from source rocks, it is concluded that the upper Paleozoic natural gas in Erdos basin is coal-derived gas, which was concentrated and accumulated near the source. This conclusion promoted the development of compact sand reservoir forming theory, and provided effective guidance upon the exploration of natural gas in basins.

5 R&D EQUIPMENT

The key lab for natural gas reservoir forming and development is equipped with 61 sets of middle to large experiment equipment, including rare gas isotope mass spectrometer, natural gas accumulation simulation system, large MAT253 isotope mass spectrometer, Delta Plus XL Isotope-mass spectrometer, Delta-S Isotope-mass spectrometer, chromatography/mass spectrometry, inclusions analyzer, confocal laser scanning microscope, gas chromatography analysis instrument, diffusion coefficient analyzer, organic carbon analyzer, oil & gas evaluation tool, etc. With these R&D equipment, the staff are able to carry out natural gas and rock pyrolysis light hydrocarbon, natural gas biomarker compound and rock hydrocarbon generation and expulsion simulation experiments, to analyze carbon and hydrogen isotope of monomer hydrocarbons and isotope of non-hydrocarbon and noble gases, to conduct physical simulation of natural gas reservoir forming and analyze inclusions, as well as to evaluate cap rocks.

Natural gas generation and expulsion simulation device

MAT253 isotope mass spectrometer

Rare gas isotope mass spectrometer

Gas chromatograph

Laser scanning confocal microscope

Gas reservoir forming simulation system

6 QUALIFICATIONS & STANDARDS

6.1 Qualifications

Founded in the year of 2000, the key lab for natural gas reservoir forming and development was awarded with the accreditation certificate (China Metrology Accreditation) by the Certification and Accreditation Administration of China and is currently in possession of 53 geological detection technologies and undertaking the key scientific research projects for the country and companies as well as key projects in six major gas areas. It has won107 awards, including 5 at national level, 40 at provincial level and 62 at bureau level. It has published more than 450 papers and 26 books.

6.2 Standards

The key lab for natural gas reservoir forming and development of the CNPC has presided over and participated in the establishment of 6 national and industrial standards relating to natural gas exploration and 8 relevant patents.

Patent and Standard	Standard and Patent No.
Mill pot for preparation of rave gas in inclusions of rocks	ZL201220123378.7
A sample preparation system based on extraction and separation of inert gas	ZL 201020269937.6
Testing device in core permeability rate experiment under formation pressure	ZL201120467474.9
Tester for absorption under high temperature and high pressure	ZL201110004691.9
Portable tester for shale gas and coalbed gas	ZL201010621116.9
A sample preparation system based on the extraction and separation of noble gas and its application	201010236355.2
Mill pot for preparation of noble gas in inclusions of rocks and preparation method	201210186623.6
Method for analyzing biomarker in natural gas	201210100118.2
Method for analyzing carbon and oxygen isotope of organics and carbonates	SY/T 5238-2008
Biomarker Fest in sediments and crade oil by gas chromatography—mass spectrography	GB/T 18606-2001
Method for testing static nitrogen adsorption volume based on specific surface and pore size distribution of rocks	SY/T 6154-1995
Method for testing porosity and permeability of rocks under overburden pressure	SY/T 6385-1999
Classification of gas reservoir	SY/T 6168-2009
Coalbed gas resource/reserve specification	DZ/T 0916-2009

7 EXPERT TEAM

Dai Jinxing Academician of Chinese Academy of Science, natural gas geologist and geochemistrist. Long engaged in teaching and research of natural gas geochemical characteristics and theory. Representative works include The Abiogenic Gas and Formation Conditions in Eastern China, and The Formation and Distribution of Medium-Large-Sized Gas Fields in China. He won the first prize for progress in science and technology at national level in 1987 and 1997 respectively and won the second prize in progress in natural science at national level in 2010.

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Wei Guoqi Doctor, professional level senior engineer, doctoral supervisor, senior technician. Long engaged in integrated research and exploration of natural gas, in charge of national key projects on natural gas in “the 8th five- year plan” through “the10th five- year plan” and national key projects in “the 11th five-year plan” and “the 12th five-year plan”, he has made significant contribution to the discovery of Gaoshiti—Moxi Sinian—Lower Palaeozoic gas field. He won 1 second prize and 1 third prize for progress of in science and technology at national level and 11 at ministerial level, He has published 122 papers and co-authorized 11 books.

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Jiao Guihao Doctor, professor level senior engineer, senior technician. Mainly engaged in integrated research in oil and natural gas geology and planning & arrangements, He has accomplished more than 40 scientific research projects and design for more than 100 exploration wells independently. and won 7 achievement awards at provincial/ ministerial level and 30 at bureau level. He has co-authored 3 books and published 17 papers.

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Li Jian Doctor, professor level senior engineer. Long engaged in natural gas geochemistry and accumulation research, natural gas resource evaluation and oil sand resource investigation. He has accomplished more than 50 scientific research projects, participated in national key projects on natural gas in "the 8th five- year plan period" through "the10th five- year plan period" and key national projects in "the 11th five-year plan" and "the 12th five-year plan". He won 1 second prize in natural science at national level, 12 achievement awards at ministerial level and 18 at bureau level. 102 papers and 10 books published.
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Sun Ping Doctor, senior engineer, senior technician. Long engaged in regular research and exploration of oil & gas, coal bed gas geology, and ever in charge of research and exploration of oil & gas in Erlian and Jizhong exploratory areas and Qaidam Basin as well as exploration of coal bed gas in Qinshui Basin. He has proposed location of more than 80 exploration wells, and organized oil exploration in about 300 wells, and accomplished nearly 30 scientific projects. He won 5 achievement prizes at provincial/ ministerial level and 3 at bureau level, with more than 20 papers published.
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Yang Wei Doctor, senior engineer. Mainly engaged in oil & gas exploration geological research on sedimentology, sequence stratigraphy, reservoir characteristics and integrated evaluation of play and trap, he has successively taken charge of or participated in more than 30 scientific research projects, and made great contribution to the discovery of Longgang gas reservoir and Moxi intraplatform shoal gas reservoir. He has won 3 achievement prizes at provincial/ ministerial level and 7 at bureau level, and co-authored 2 books and published more than 40 papers.
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Zhang Fudong Doctor, senior engineer. Mainly engaged in natural gas strategic research, middle and long-term planning and annual arrangement, regional geology and basin evaluation, play and trap evaluation, natural gas accumulation geology and oil & gas enrichment. He has contributed to 25 research projects and won 3 achievement prizes at provincial/ ministerial level and 8 at bureau level. He has co-authored 4 books and published 10 papers.

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Yi Shiwei Doctor, professor level senior engineer. Long engaged in oil & gas geology research and exploration, he has taken charge of or participated in more than 50 scientific research projects. Based on rich experience in actual exploration, he put forward a method to explore and evaluate the lithostratigraphic oil & gas reservoir. He won 1 second prize for progress in science and technology at national level, and 10 prizes at ministerial level, and published 40 papers and co-authored 8 books.

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Wang Dongliang Doctor, senior engineer. Mainly engaged in integrated evaluation and research on oil & gas geochemistry, oil & gas accumulation and oil & gas geology, etc, He has taken charge of or participated in more than 30 research projects, and won 6 awards at provincial/ministerial level and 9 awards at bureau level, and has contributed to the compilation of 4 books and published 44 papers in core periodicals.

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Li Zhisheng Master, senior engineer. Long engaged in oil & gas geochemistry experiment and research. He has taken charge of or participated in more than 20 projects, and won 6 awards at provincial/ministerial level and more than 15 awards at bureau level, and has published more than 30 papers, and co-authored 4 books.
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Xie Zengye Doctor, senior engineer. Long engaged in integrated research of oil & gas geochemistry, resource evaluation and accumulation, etc. He has taken charge of or participated in more than 50 projects, and won 14 awards at provincial/ministerial level and more than 20 awards at bureau level, and has published more than 60 papers, and co-authored 5 books.
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Zhao Zehui Doctor, senior engineer. Mainly engaged in integrated research on structural geology, volcanic rocks, compact glutenite reservoir and natural gas exploration, he has taken charge of or participated in more than 14 scientific research projects, and won 1 award at provincial/ministerial level and 6 awards at bureau level, and co-authored 1 book and published more than 20 papers.
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