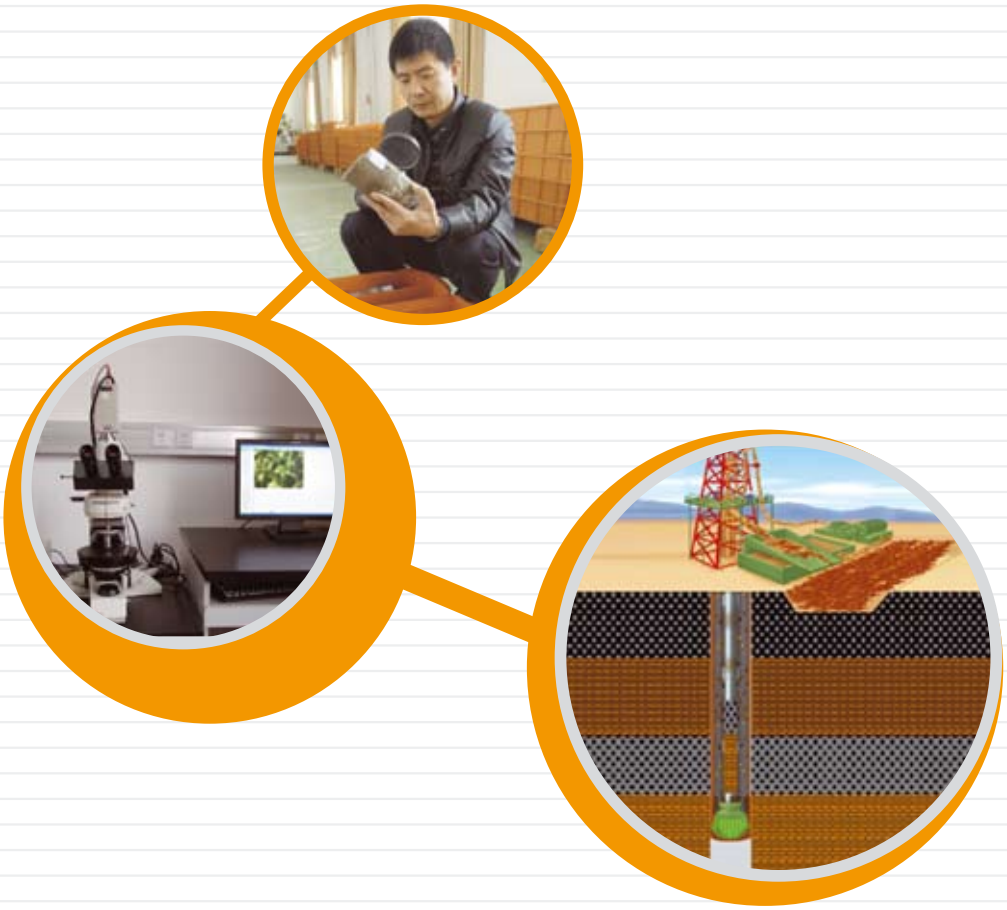
Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Layers

Science & Technology Management Department

2011



CHINA NATIONAL PETROLEUM CORPORATION

CNPC's Geological Logging Technology helps your interpretation of oil, gas and water layers to stay on the top!

Contents

China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. As an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integration of upstream and downstream operations, internal and external trade and production and marketing. CNPC has 17 upstream companies, 33 downstream companies and 36 large-scale marketing companies. It is China's largest producer and supplier of oil and gas, and also one of the largest refined oil products and petrochemicals. In 2010 CNPC produced 105 million tons of crude oil and 72.5 billion cubic meters of natural gas, while crude processing volume reached 135 million tons. The total revenue of RMB1,720 billion with a profit of RMB172.7 billion had been achieved the same year. Its profit is among the highest of the domestic enterprises in China.

CNPC was ranked 10th in Fortune Global 500 in 2010 and 5th among global top 50 oil companies.

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.

The Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Layers is one of representatives for major innovations of CNPC.

CLEAN ENERGY SUPPLY FOR BETTER ENVIRONMENT

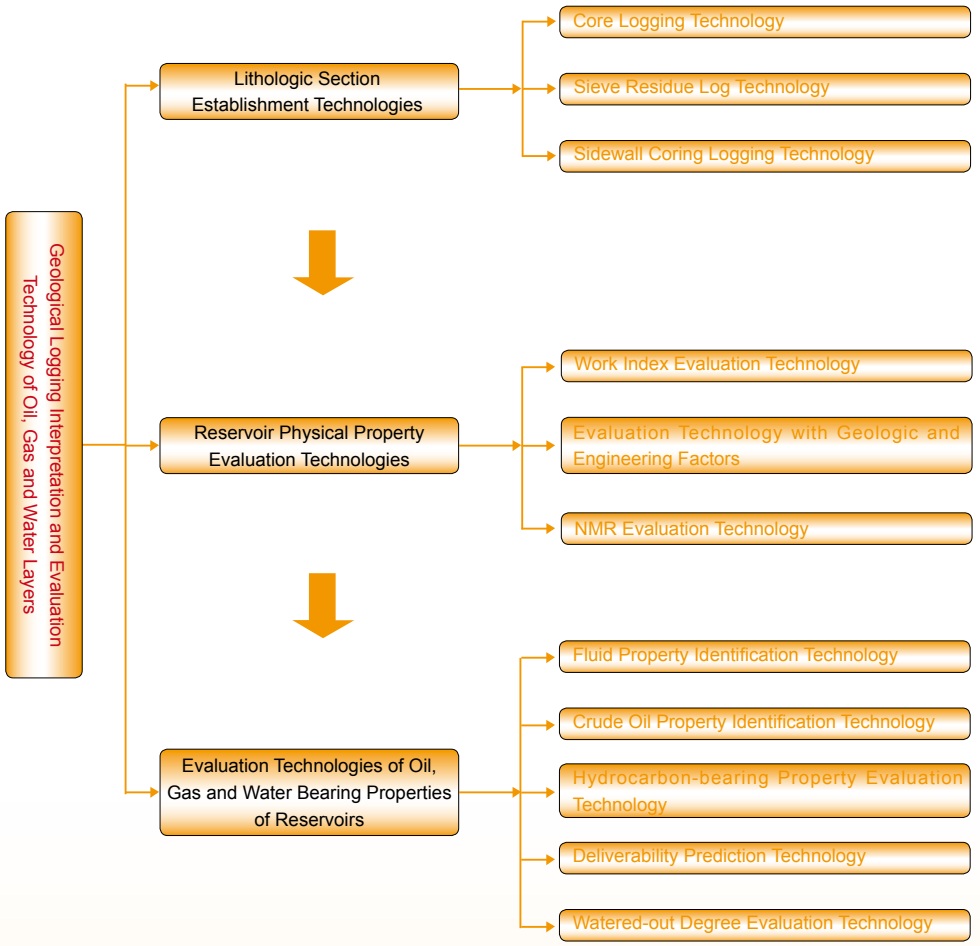
1 INTRODUCTION

The Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Layers is a wellbore technology of positioning oil, gas and water zones and providing the basis of selecting zones for well testing and fracturing.

In recent decades, CNPC has been devoted to the research and experiments on logging technology and formed a complete set of logging technologies, among which the Interpretation and Evaluation Technology of Oil, Gas and Water Layers is a kind of high-end technology integrating geophysical exploration, well logging, well testing and producing test techniques and various logging techniques. It can provide users with economical and practical services of lithlogic section establishment, evaluation of reservoir physical properties and interpretation and evaluation of oil, gas and water zones.

As the important means of enhancing the oilfield exploration success ratio and increasing oilfield's reserves and production, the Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Layers has been widely applied in the exploration and development of over ten oilfields at home and abroad. For example, the technology has been applied in the interpretation and evaluation of over 1,000 wells in Daqing oilfield, with the accuracy rate of over 90%.

CNPC has analytical laboratories with advanced equipment, over 500 excellent interpretation and evaluation staff and hundreds of specialized logging service teams and can provide various technical services related to wellbore geological logging as well as interpretation and evaluation of oil, gas and water layers.


Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Layers
Lithologic Section Establishment Technologies
Core Logging Technology
Sieve Residue Log Technology
Sidewall Coring Logging Technology
Reservoir Physical Property Evaluation Technologies
Work Index Evaluation Technology
Evaluation Technology with Geologic and Engineering Factors
NMR Evaluation Technology
Evaluation Technologies of Oil, Gas and Water Bearing Properties of Reservoirs
Fluid Property Identification Technology
Crude Oil Property Identification Technology
Hydrocarbon-bearing Property Evaluation Technology
Deliverability Prediction Technology
Watered-out Degree Evaluation Technology

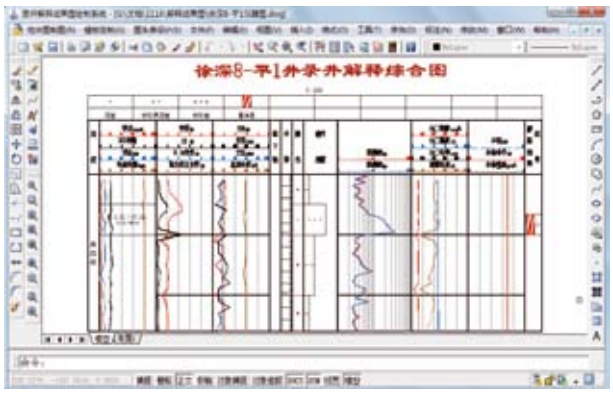
2 UNIQUE TECHNOLOGIES

2.1 Lithologic Section Establishment Technologies

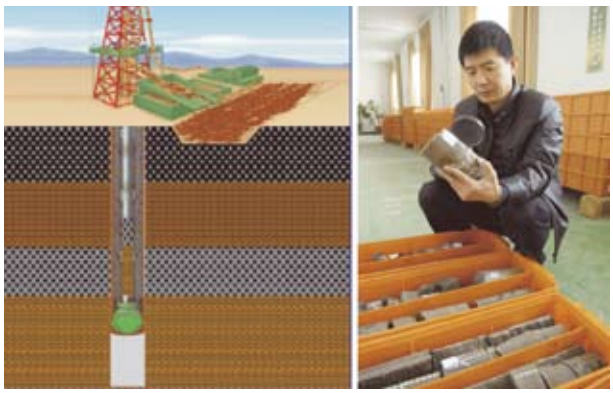
Lithologic Section Establishment Technologies refer to: carrying out the whole-process wellbore monitoring of tangible logging data such as cuttings, cores and sidewall coring data, etc., denominating lithology by virtue of expert's experience and precision instruments, and establishing high-precision stratigraphic lithologic sections. The coincidence rate is up to over 90%. The Lithologic Section Establishment Technologies are necessary means for customers to perfect their geologic recognition of target exploration areas.

(1) Core Logging Technology

The Core Logging Technology is a kind of lithologic section establishment technology of description and analysis of drilling cores.



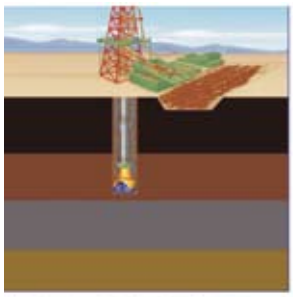
Result Plotting System

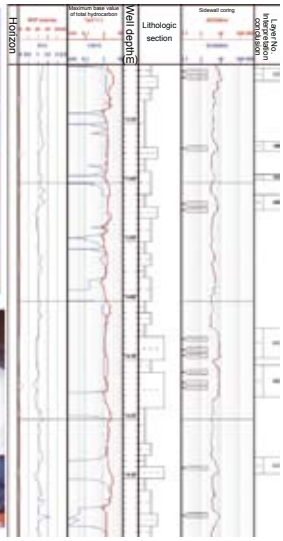


Reservoir index and characteristic data can be acquired by means of core analysis. The Core Logging Technology involves hydrocarbon abundance and stage, the determination of regional exploration and development prospect, reservoir's net thickness and physicochemical characteristics, the determination of lithology, physical property, oil-bearing property and electrical property and their relations, calculation data of analyzing and judging sedimentary environment and field reserves, palaeontologic characteristic data, stratigraphic age determination and the data of stratigraphic dip, contact relation, faults, rock fissures and holes, thus providing the basis for studying field types and determining development systems and plans.

(2) Sieve Residue Log Technology

The Sieve Residue Log Technology is for continuous collecting of cuttings as per a certain





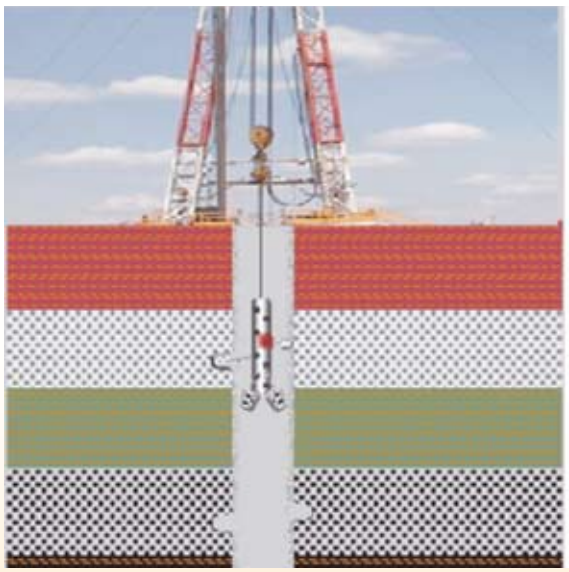
spacing interval during drilling and then cleaning, homing and description of them so as to recover the formation development conditions.

The new method summarized by CNPC to analyze and study underground lithologic development conditions and judge oil, gas and water resources using cuttings is scientific, effective, convenient and able to save substantial exploration investment for customers.

(3) Sidewall Coring Logging Technology

The Sidewall Coring Logging Technology is for spot sampling in borehole wall, describing and analyzing samples and determining lithology and oil and gas show after well logging according to actual needs.

The Sidewall Coring Logging Technology provides the best supplement for lithologic section establishment. Particularly, the technology can help to effectively determine and verify complex strata.



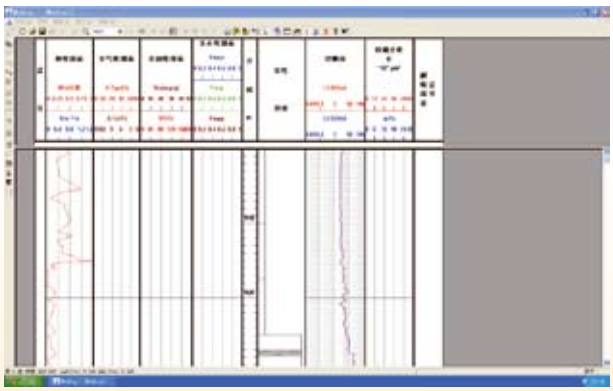
2.2 Reservoir Physical Property Evaluation Technologies

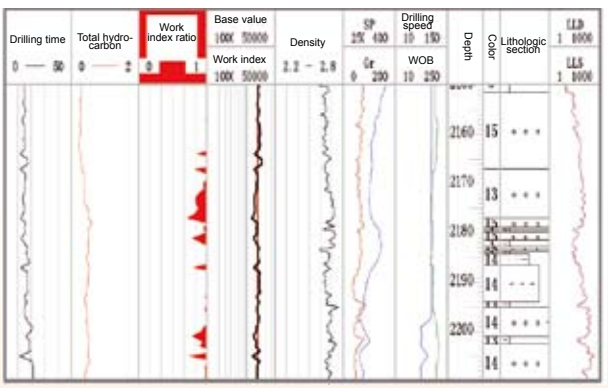
The Reservoir Physical Property Evaluation Technology is a kind of technology of quantitative or semi-quantitative evaluation of reservoir's physical properties by means of comprehensive analysis, processing and interpretation of the data acquired at a logging site. Through many years of research, development and exploration, CNPC has developed the matching Physical Property Evaluation Software and can provide users with various physical property evaluation services.

Physical Property Evaluation Software

(1) Work Index Evaluation Technology

The Work Index Evaluation Technology is for evaluating the reservoir's physical properties according to rock compactness and the relative anomaly of drilling engineering parameters when drilling into the high-pressure formation, and is particularly applicable to the evaluation of fractured reservoirs. The quick and flexible mapping software, Mudlog, can intuitively reflect the quality of drilling engineering parameters and reservoir's physical parameters. The successful application of the technology in Qingshen Gas Field and Hailar Oilfield has created enormous economic benefits.





Mudlog Software Operation Interface and Result Chart

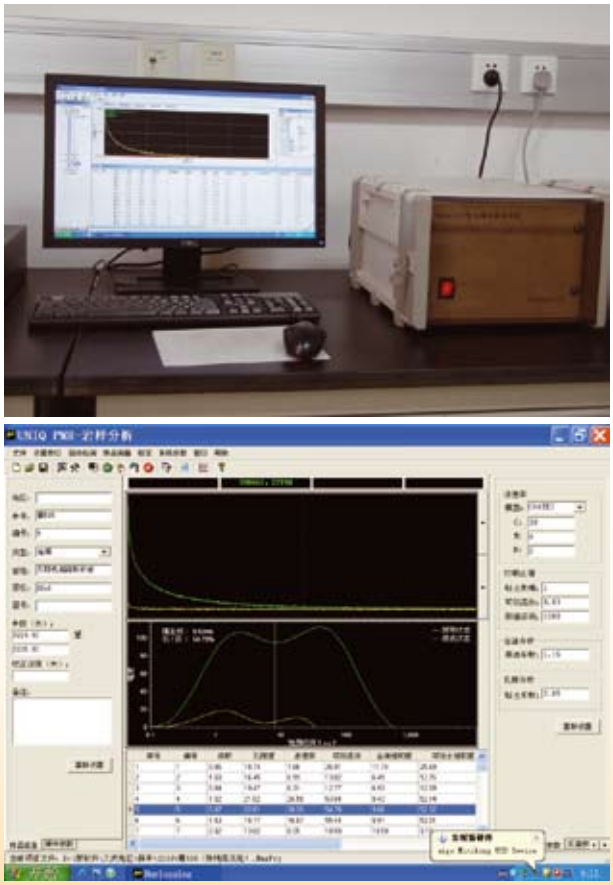
(2) Evaluation Technology with Geologic and Engineering Factors

The evaluation of reservoir's physical properties with geologic and engineering factors is to characterize rock compactness via the drilling time after eliminating geologic and engineering factors on the premise of similar formation pressure coefficient. By studying engineering parameters, an abnormal difference in engineering parameters of different types of reservoirs has been concluded. The unique reservoir physical property evaluation technology with geologic and engineering factors is particularly applicable to the evaluation of physical properties of volcanic reservoirs, with the accuracy rate of over 80%. CNPC has various high-end, medium-end and low-end Compound Logging Units (e.g. ALS2.3, SDL-9000 and SK-2000), which can carry out real-time data acquisition and analysis of engineering parameters in different drilling environments and accurately evaluate reservoir's physical properties.

Engineering Parameter Acquisition and Processing Platform of ALS2.3 Compound Logging Unit

(3) NMR Evaluation Technology

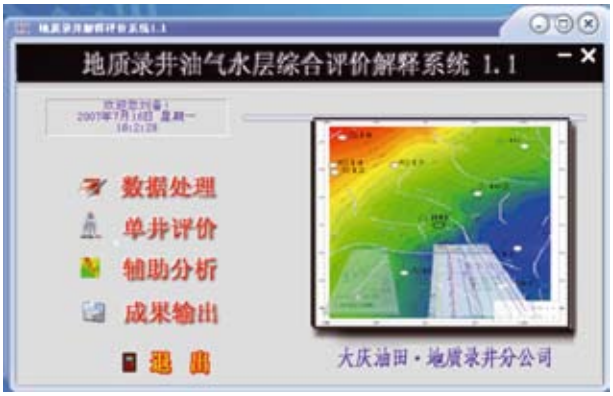
The NMR Evaluation Technology is an important means for determining and evaluating the quantitative distribution of reservoir porosity, permeability and rock throat radius and predicting reservoir deliverability according to relaxation time spectrum. Compared with other test methods, the NMR Evaluation Technology can obtain quantitative porosity and permeability more conveniently and quickly. CNPC has different types of nuclear magnetic resonance apparatus. The confidence level of the parameters such as porosity and permeability acquired by the apparatus can reach 85%.



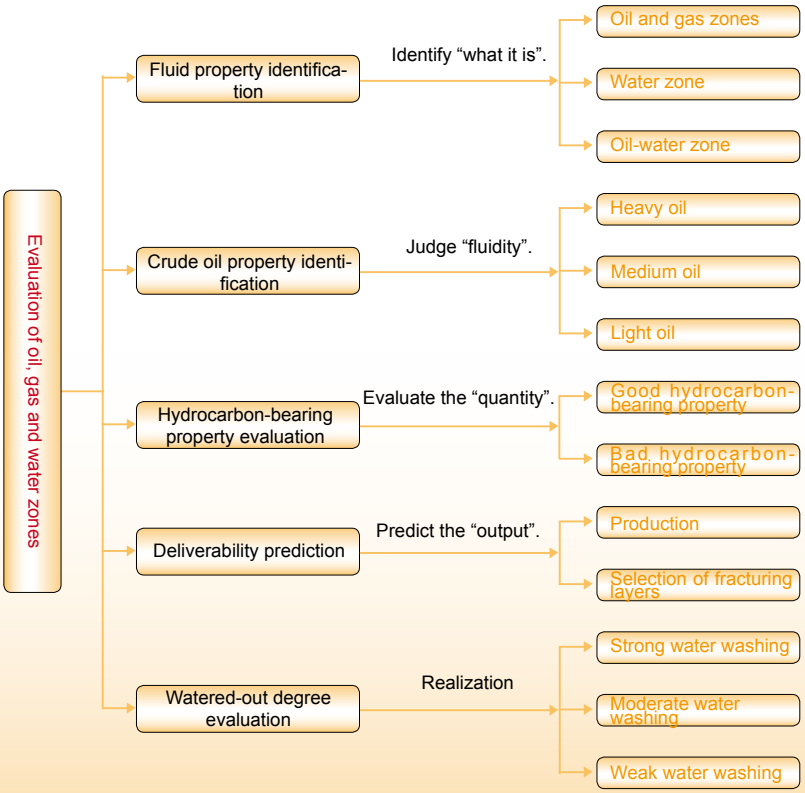
NMR Apparatus and Its Operation Interface

2.3 Evaluation Technologies of Oil, Gas and Water Bearing Properties of Reservoirs

Years of studies and applications has yielded a complete set of technologies involving mature fluid property identification, crude oil property identification, hydrocarbon-bearing property evaluation, deliverability prediction and watered-out degree evaluation and a corresponding software support platform has been developed, thereby providing forceful technical support for improving exploration and development efficiency, reducing the risk of exploration and development, accurately judging the oil, gas and water bearing state of reservoirs and promoting the adjustment and tapping potential in the middle and late periods of oilfield development.



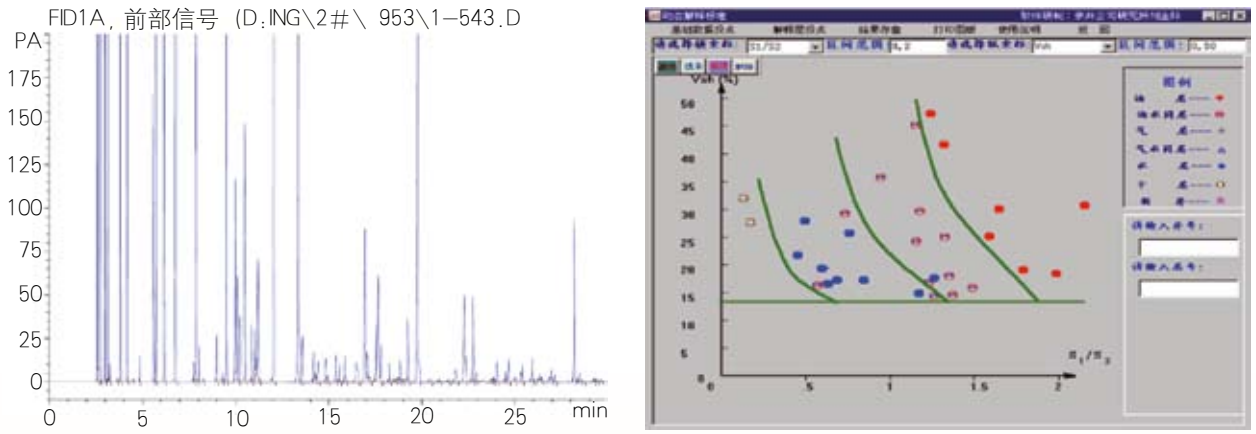
Interpretation and Evaluation Software



(1) Fluid Property Identification Technology

CNPC has formed a complete set of mature identification methods for oil layers, water layers and oil-water layers. The methods can be used to accurately determine fluid properties for customers.

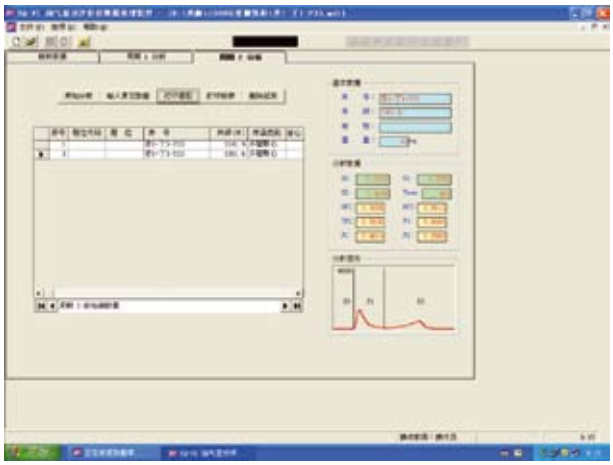
The identification of fluid properties is an important link of exploration. Many kinds of data, such as compound logging data, rock pyrolysis analysis and gas chromatograph data, etc., respond to fluid properties to different extents. Effective evaluation parameters are selected from these data and used to establish the fluid property identification plates which are applicable to various strata such as high resistance water zones, low resistance oil zones, light oil zones, heavy oil zones, residual oil and water bearing zones and compact reservoirs, etc. The fluid property identification plates can be used to recognize the reservoir fluid properties qualitatively.

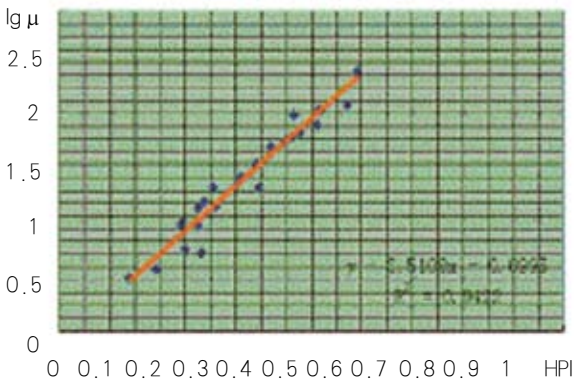


Light Hydrocarbon Analysis Result Chart and Multi-Parameter Fluid Property Identification Plate

(2) Crude Oil Property Identification Technology

Crude Oil Property Identification is an issue of paramount importance to the hydrocarbon evaluation. Testing methods and fracturing stimulation technologies are different for heavy oil, medium oil and light oil. The Crude Oil Property Identification Technology is to identify crude oil properties according to different responses of different properties of crude oil in rock pyrolysis and saturated hydrocarbon gas chromatography. We have specialized equipment such as rock pyrolysis apparatus, component analyzer and saturated hydrocarbon gas chromatograph, etc. as well as crude oil property quantification standards, with the accuracy rate of 85%. We can provide customers with qualitative or quantitative recognition of crude oil properties and assist in scientific decision making in the crude oil production stages.

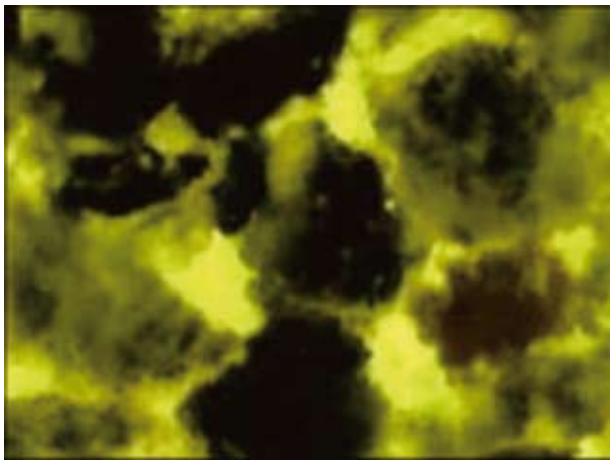


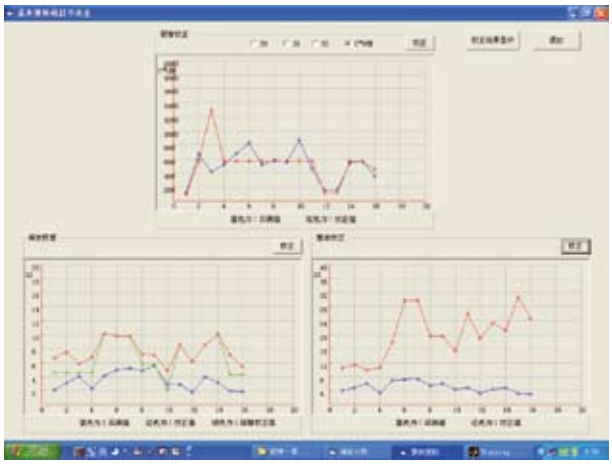


Crude Oil Viscosity Prediction Plate

(3) Hydrocarbon-bearing Property Evaluation Technology

The oil-bearing property of oil-bearing samples is lost to some extent while the samples are returning to surface via drilling fluid carrier. To correct this loss and objectively know reservoir's hydrocarbon-bearing property, a complete set of Geochemical Correction Software has been successfully developed through a large number of studies and experiments. By calculation from the corrected data and empirical formula, the hydrocarbon-bearing property of reservoirs can be recognized quantitatively and the oil-bearing property of reservoirs can be evaluated finely.

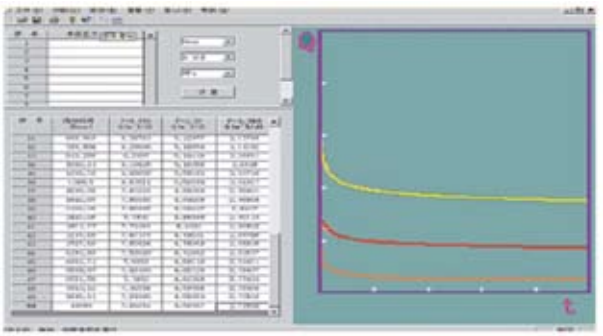




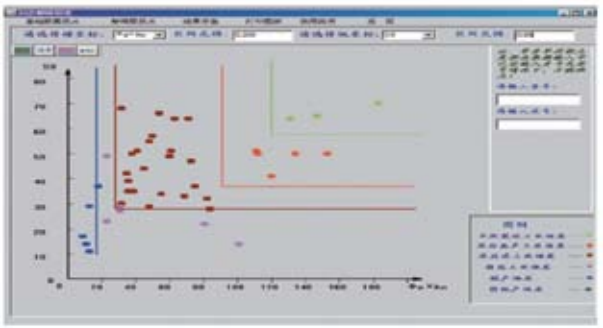
Fluorescence Micrograph and Geochemical Correction Software

(4) Deliverability Prediction Technology

The static reservoir deliverability prediction method has been established by taking the porosity, permeability, oil saturation, gas saturation and net thickness, etc. of reservoirs as the main static evaluation parameters. In addition, the dynamic deliverability prediction method for the relationship between the bottom hole flowing pressure and production has been established on the basis of percolation mechanics theory. By combining the static deliverability prediction method with the dynamic deliverability prediction method, a production test plan can be determined scientifically and reasonably and stimulations can be implemented. CNPC can provide customers with different types of reservoir deliverability prediction services and has the deliverability prediction software —Geolog® with independent intellectual property. The software, featuring easy operation and high stability, is applicable to different operating systems.



油层动态产能计算图

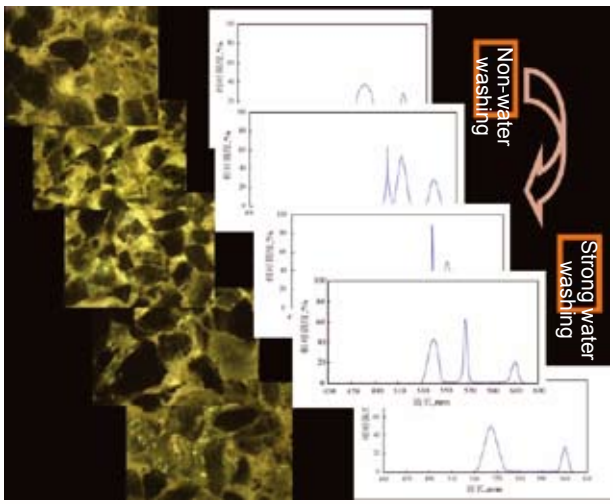


油层静态产能评价图版

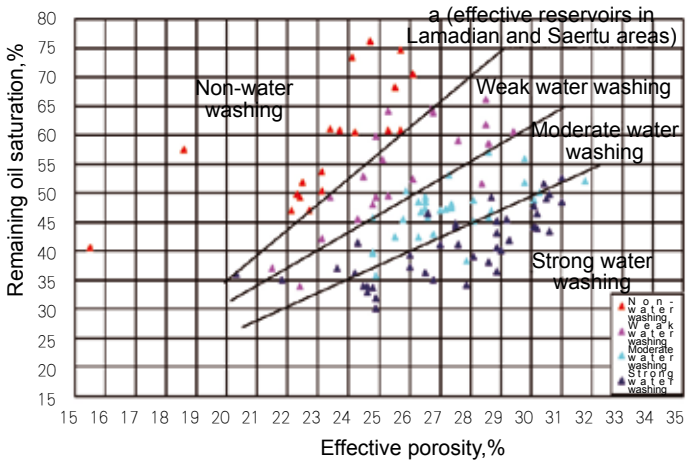
Deliverability Prediction Plate

(5) Watered-out Degree Evaluation Technology

The Watered-out Degree Evaluation Technology is a kind of technology of evaluating the watered-out degree of a heterogeneous reservoir in its high water cut stage in the late period of development. We can accurately determine the remaining oil enrichment sites and evaluate the oil-bearing potential of external zones, thus providing important reference basis for increasing oilfield's production and benefit and selecting perforation zones. The developed software of "Water-flooded Zone Logging Interpretation Parameter Processing System" realizes automatic data processing, intellectualized data interpretation, working platform visualization, operation flow collaboration and system function integration.



Fluorescence Image Features of Water Washing Degrees



Water-flooded Zone Logging Interpretation Software

3 TYPICAL CASES

3.1 Logging Interpretation of Well B302 in Hailar Oilfield

Hailar basin in Inner Mongolia of China is a rifted sedimentary basin. The oil in this basin is extremely volatile. In terms of electrical property, the basin is characterized by low resistance water zones and it is very difficult to discriminate oil from water. Thus, the basin is like “chicken ribs” for petroleum exploration.

Well B302 is an appraisal well in Beier sag of Hailar basin. Oil-bearing shows were found in 10 layers of Nantun Fm. during the drilling of this well (Figure 1), and log data indicate light oil feature (Figure 2). The logging interpretation result shows oil zones (Figure 3). The post-fracturing production capacity from logging prediction is 125t/d (Figure 4) and the actual post-fracturing production capacity is 135.8t/d. Successful interpretation of this well has opened up a new situation of exploration in Hailar basin.

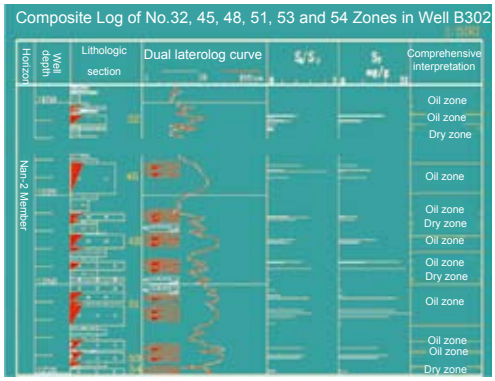


Figure 1 Composite Log of No.32~54 Zones in Well B302

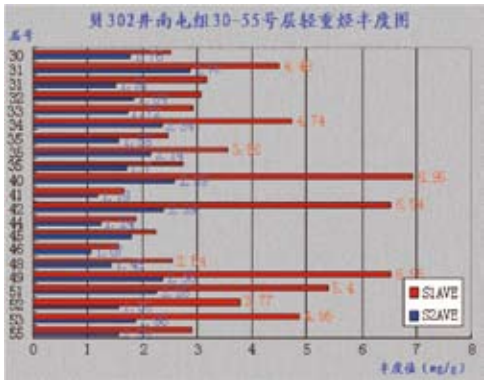


Figure 2 Light and Heavy Hydrocarbon Abundance Graph of Well B302

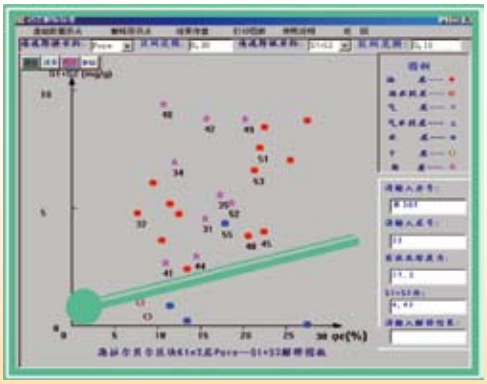


Figure 3 Reservoir Fluid Property Identification and Interpretation Graph of Well B302

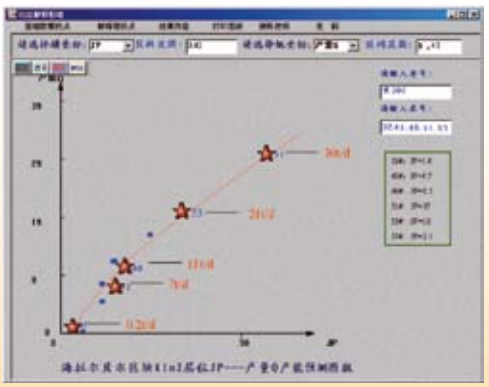


Figure 4 Deliverability Prediction Plate of Well B302

3.2 Watered-out Degree Evaluation of Daqing Oilfield

With continuous increase in the development degree of Daqing oilfield, the water cut of oil zones is being increased day by day. The overall water cut of major oil zones in the oilfield has now exceeded 90%. The heterogeneous reservoirs in Daqing oilfield and the different water cuts of various oil zones made it a difficult problem for stable production and benefit increase to accurately determine the watered-out degree of various oil zones. The application of the watered-out degree evaluation technology has obtained a very good effect. By using the technology, the cumulative increased recoverable reserves are over 200,000 tons and the created economic benefit over RMB 0.1 billion.

In Xingnan 10 area, an oil production area of Daqing oilfield, the comprehensive water cut has reached 89.9%, hence it is a high water cut oilfield. Rock pyrolysis, saturated hydrocarbon gas chromatography and microscopic fluorescence micrograph analyses were performed on the sidewall coring samples from the 16 ones out of 92 tertiary infill wells in advance. As per the logging evaluation result, the basis for selecting perforation zones was determined so that the average water cut in the 16 wells was decreased by 13.1%. In the case of only 15m perforated thickness, the oil production exceeds the average in this area, and thus remarkable effects were obtained. By referring to the logging results of the previous 16 wells, the evaluation standards for the subsequent 76 wells were revised and the basis for selecting perforation zones was determined so that the average water cut in the 76 wells was decreased by 7.3%, hence it has a good effect of stabilizing oil production and controlling water cut.

Commissioning Statistics Table 1

Type	Average perforated thickness m	Average daily oil production of a single well t	Comprehensive water cut (%)
16 on-stream sidewall coring wells	15.0	2.13	76.8
76 subsequent on-stream wells	21.7	2.09	82.6
Totally 92 tertiary infill wells	20.5	2.10	81.8

4 R&D EQUIPMENT

Compound Logging Unit: It acquires drilling fluid parameters, oil and gas parameters and engineering parameters by means of gas chromatography and sensors and can be used to evaluate physical property and hydrocarbon-bearing property of reservoirs.

Polarized Fluorescence Microscope: Rock samples are made into fluorescent slices, and fluorescence color, brightness, color difference and light-emitting area and oil and water occurrence state, etc. are described quantitatively under the microscope, thereby identifying reservoir oil properties as well as oil and water zones and evaluating water-flooded zones.

Rock Pyrolysis Apparatus: Based on the theory of pyrolysis and oxidation, the apparatus quantitatively analyzes the content of gaseous hydrocarbon, liquid hydrocarbon, pyrolysed hydrocarbon and residual carbon in rocks, thus obtaining parameters such as oil saturation, oil abundance and productivity index, etc., discriminating real hydrocarbon reservoirs from false ones, determining crude oil properties and quantitatively evaluating reservoirs and source rocks.

NMR Apparatus: Based on the pulsating NMR principle, the apparatus analyzes the parameters such as porosity and permeability, etc. in rock samples. The apparatus, characterized by small volume, convenience, many analysis samples at a time and high data analysis accuracy, can be used to evaluate reservoir's physical properties.

Light Hydrocarbon Analyzer: It mainly analyzes over 100 hydrocarbon monomers such as linear paraffin, isoalkane, cyclane and aromatics lower than C9 in oil and gas in reservoir pores. The analyzer is used to identify reservoir fluid properties and evaluate water-flooded zones according to the variation of the typical ratio of iconic hydrocarbon monomers.

5 QUALIFICATION AND Standard

5.1 Qualification

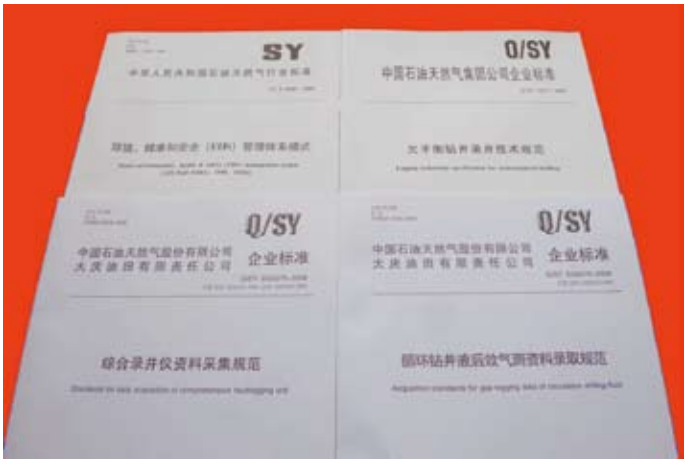
CNPC's geological logging technology service has passed the certification of Environmental Management System, Occupational Health & Safety Management System and Petroleum Engineering Technical Qualification, etc.

Environment Management System Certification

Occupational Health & Safety Management System Certification

5.2 Standard

CNPC is constantly perfecting its logging services according to the international industrial standards such as API. CNPC's technologies and product units are completely in line with those in the industry.



Standard

5.3 Patents

CNPC has successively won 6 logging service patents, which constitute an important part of its core technologies.

- An Automatic Liquid Level Tracking System of Logging Degasser
- A Double-range CO2 Infrared Analyzer with Double Gas Chambers
- A Satellite Receiving Antenna Protector
- A Hydraulic Core Splitter
- A Plate for Solving Watered-out Degree
- An Automatic Detection Device of Compound Logging Units

6 EXPERT TEAM

Lang Dongsheng: Senior engineer and field exploration expert. He has been occupied in geological logging interpretation of oil, gas and water zones for over 20 years and has participated in the exploration of the old areas and peripheral areas of Daqing oilfield as well as Xujiaweizi gas field successively. He is one of the founders of the Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Zones. Over 22 research papers and 7 monographs written/edited by him have been published. He has won over 10 technological achievement prizes, including 11 departmental-level ones and 1 provincial/ ministerial-level one.

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Liang Jiuhong: Senior engineer and field exploration expert. He graduated from the major Chemical Material and Ore Mining of Peking University and is one of the founders of the Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Zones. He has won over 10 scientific research achievement prizes. 6 research papers and 1 monograph written/ edited by him have been published in domestic and foreign periodicals.

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Yue Xingju: Senior engineer and field exploration expert. He has long been occupied in studies and applications of Technologies of Identifying and Evaluating Oil, Gas and Water Zones. He has built a complete set of Logging Interpretation and Evaluation Technologies and is one of the founders of the Geological Logging Interpretation and Evaluation Technology of Oil, Gas and Water Zones. He has won 15 scientific research achievement prizes, including 2 provincial/ ministerial-level ones and 10 departmental-level ones. 10 research papers and 2 monographs written/edited by him have been published.

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Geng Changxi: Senior engineer and field exploration expert. He has long been occupied in studies and applications of Technologies of Identifying and Evaluating Oil, Gas and Water Zones. He has creatively organized the study of applications of Microscopic Fluorescence Micrograph Technology, Gas Chromatography Technology and Pyrolysis Technology, etc. in interpretation of hydrocarbon reservoirs and has made a study of log data in the evaluation of watered-out degree. He has won 12 scientific research achievement prizes, including 1 ministerial-level one and 7 departmental-level ones. 14 research papers and 3 monographs written/edited by him have been published.

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