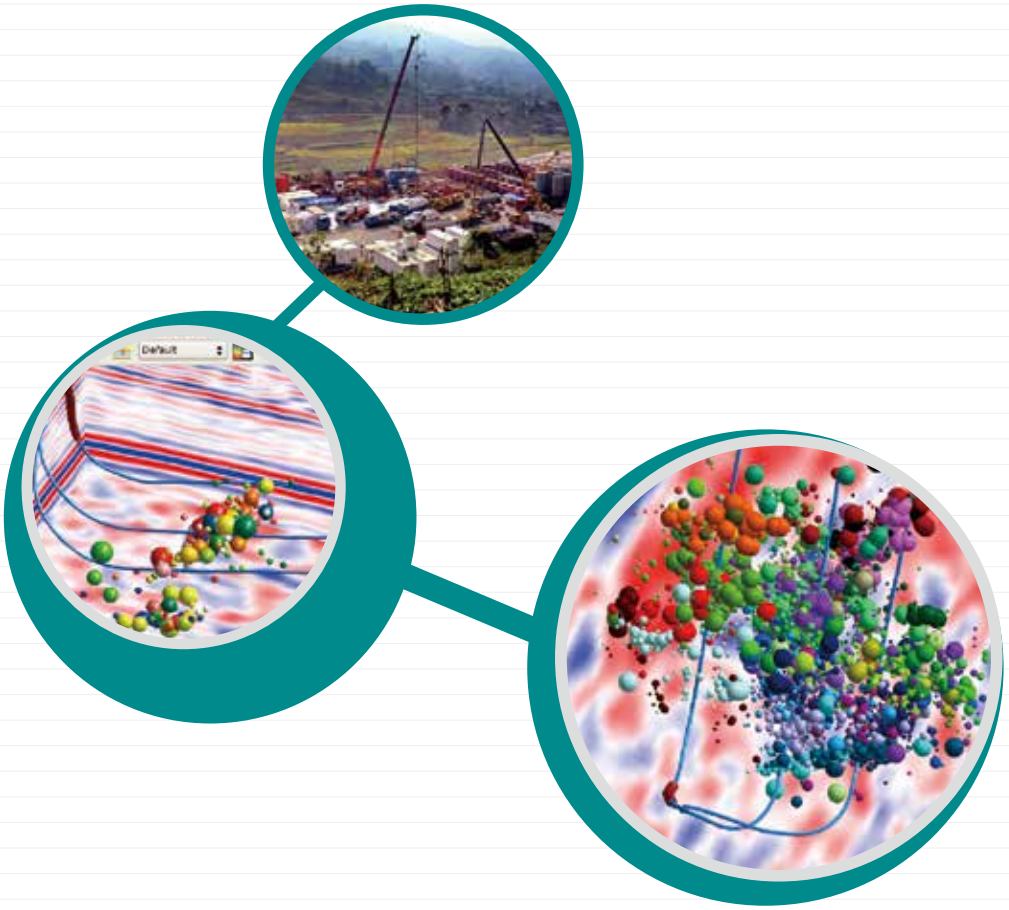
CQ-GeoMonitor Microseismic Monitoring System

Science & Technology Management Department, CNPC

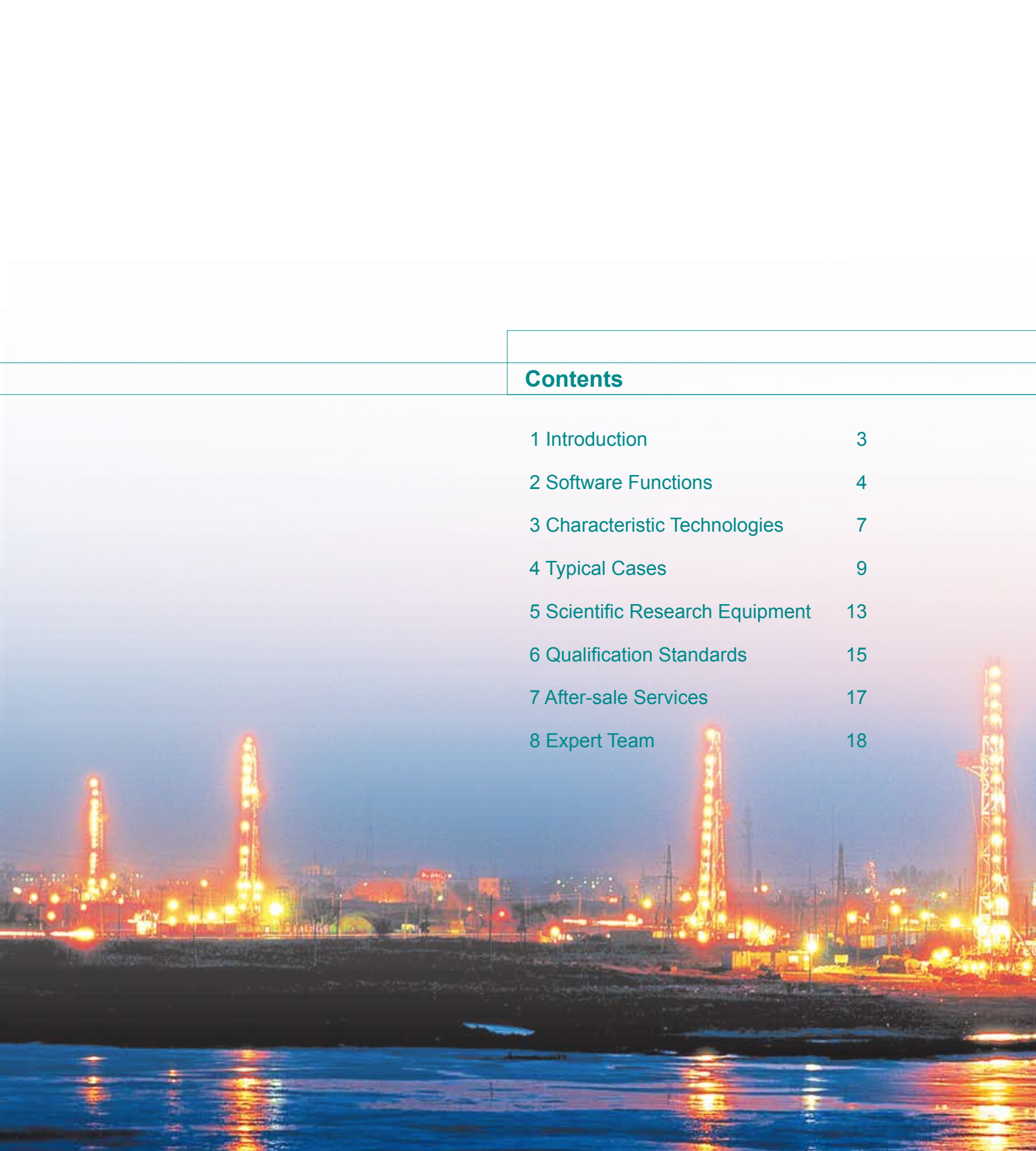
2015



CHINA NATIONAL PETROLEUM CORPORATION

Monitoring "Instantaneous Pulsation" of Underground Rocks, Clearly Seeing Dynamic Images of Fracture Extension!

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 2014 CNPC produced 113.67 million tons of crude oil and 95.46 billion cubic meters of natural gas, while crude processing volume reached 150.2 million tons. The total revenue of RMB 2,730 billion with a profit of RMB173.4 billion had been achieved the same year.

CNPC was ranked 3th among the world's largest 50 oil companies and 4th in Fortune Global 500 in 2014.

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.

CQ-GeoMonitor Microseismic Monitoring System is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

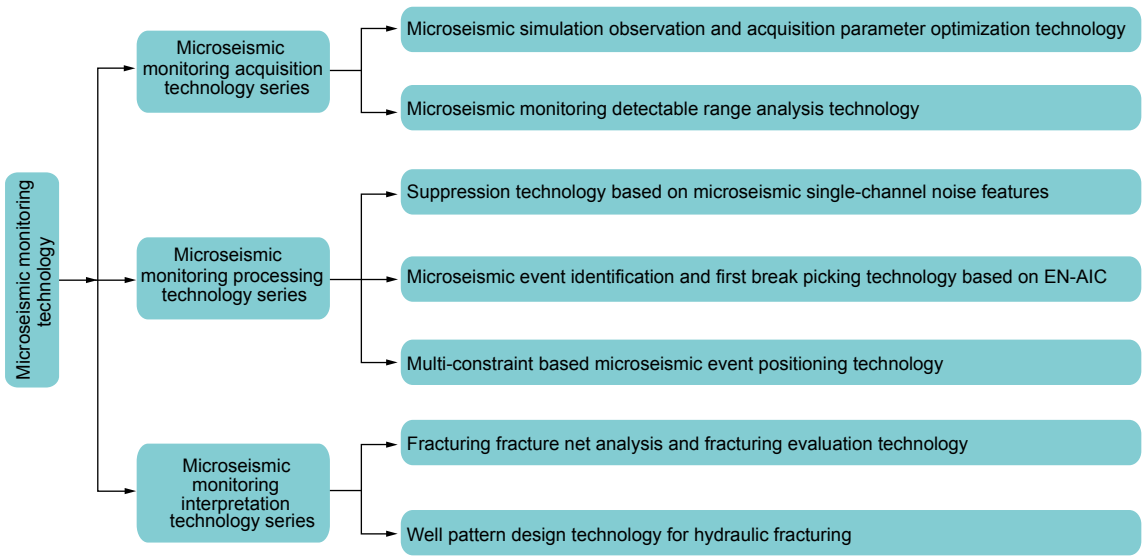
1 INTRODUCTION

The microseismic monitoring technology is an effective fracturing fracture monitoring technology with high reliability, can be used to monitor the spatial distribution of fracturing fractures in real time, and has been widely applied in fracturing fracture monitoring and reservoir dynamic detection at domestic and abroad.

CNPC has been long committed to R&D of microseismic monitoring technology and has successfully developed CQ-GeoMonitor® microseismic monitoring software system. The software system provides integrated solutions to microseismic fracturing monitoring, microseismic water drive monitoring, microseismic gas drive monitoring, etc. and is an important technology tool for exploration, development and production of unconventional oil and gas.

CQ-GeoMonitor® microseismic monitoring software system covers worldwide universal microseismic surface, shallow well and deep well monitoring technologies. The system can meet both the operation needs of microseismic monitoring of fracturing in dense well pattern areas and the needs of microseismic fracturing monitoring without monitoring well and adapt to various geologic conditions with which microseismic monitoring is confronted in different exploration and development stages.

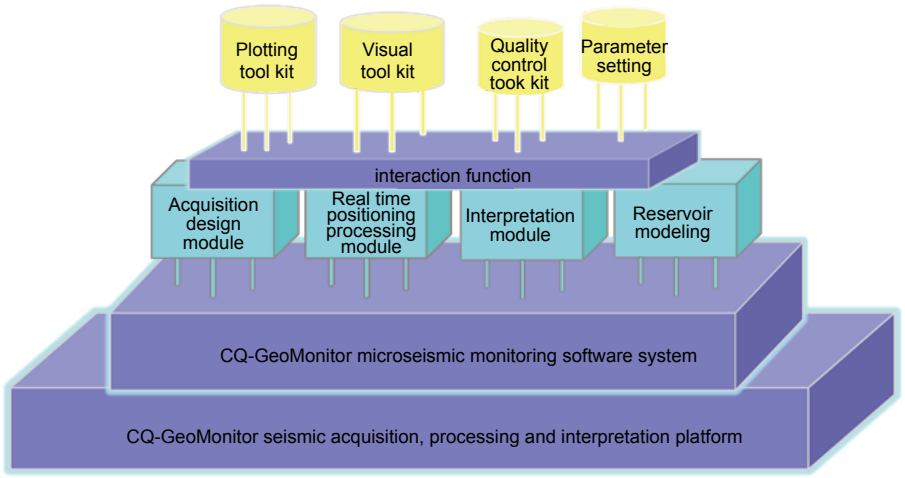
The first CQ-GeoMonitor® microseismic monitoring software system in China has promoted the development of CNPC in hydraulic fracturing monitoring and production monitoring of other oil and gas fields and increased the core competitiveness of CNPC in engineering service field.



Microseismic monitoring technology frame diagram

2 SOFTWARE FUNCTIONS

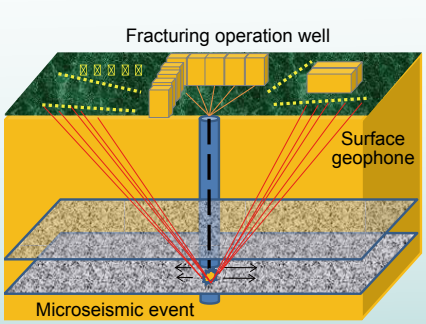
CQ-GeoMonitor® microseismic monitoring software system developed independently by CNPC can provide complete solutions which cover microseismic monitoring acquisition design, real time data processing and fracture interpretation.



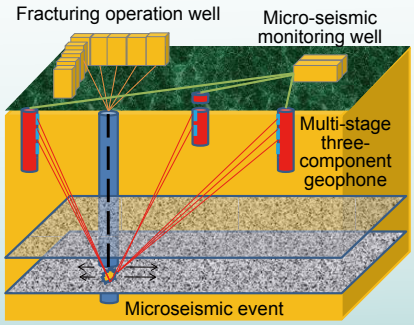
CQ-GeoMonitor® microseismic monitoring software system architecture

2.1 Multi-mode microseismic monitoring

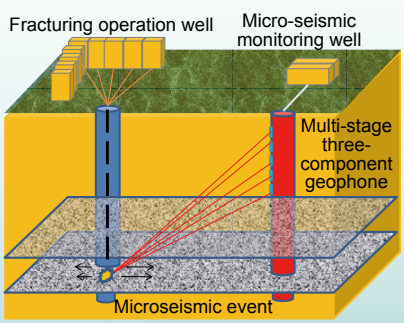
CQ-GeoMonitor® microseismic monitoring software system can provide comprehensive monitoring means under different fracturing operation conditions and has functions including microseismic surface monitoring, microseismic shallow well monitoring, microseismic deep well monitoring, microseismic combined monitoring, etc.



Microseismic surface monitoring



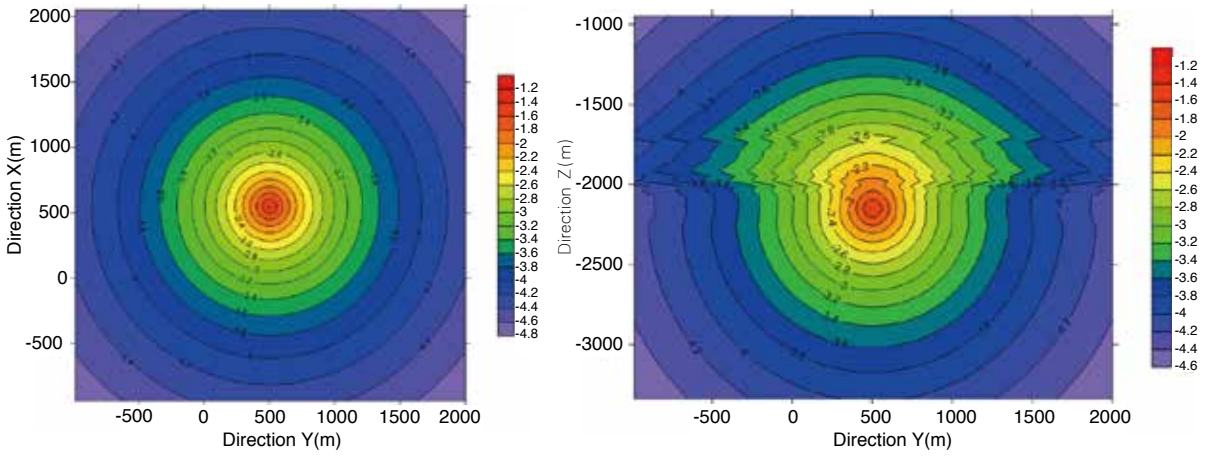
Microseismic shallow well monitoring



Microseismic deep well monitoring

2.2 Microseismic monitoring acquisition design

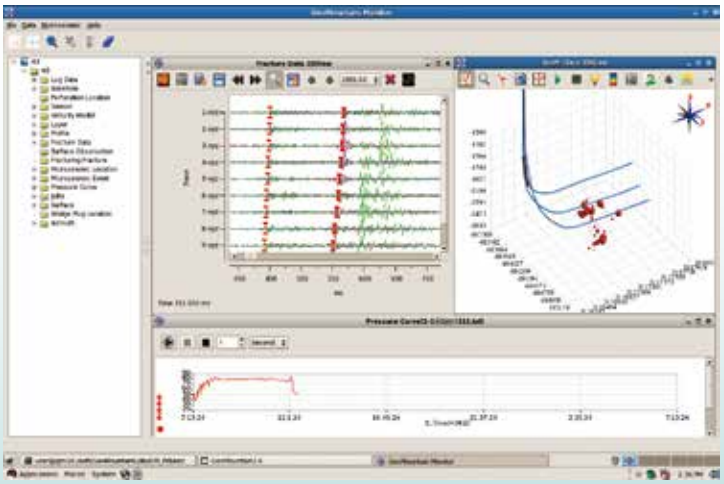
CQ-GeoMonitor® microseismic monitoring software system can be used to carry out high emulation degree simulation of the development of microseismic events according to different formation physical parameters and fracturing parameters and provides optimized microseismic monitoring design schemes for monitoring distance, observation mode, etc.



Microseismic monitoring detectable range energy simulation

2.3 Microseismic real-time monitoring

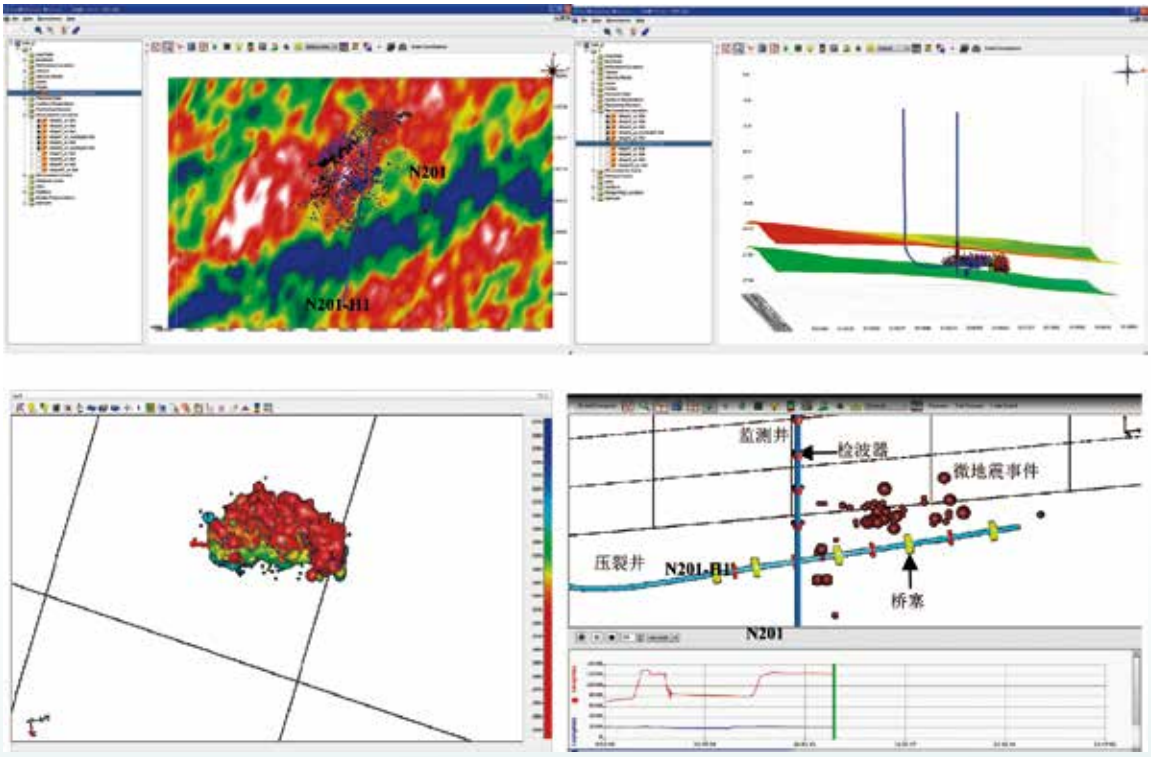
CQ-GeoMonitor® software can monitor fracturing operation dynamic in real time, automatically identify microseismic events and accurately position microseismic sources, so that users comprehensively understand the dynamic spatial distribution of fracturing fractures, thus providing bases for dynamic adjustment of fracturing parameters. The site real time processing response time of the software shall be less than 10s.



Real time monitoring interface

2.4 Collaborative microseismic data integration and interpretation

CQ-GeoMonitor® software system uses the integrated architecture and software platform of seismic interpretation software and can be compatible with the functions involving geology, logging, seismic data, 3D visualization, etc. all the more compared with foreign software. This makes for fully combining seismic, geologic, logging, fracturing and microseismic data and improving the reasonableness and reliability of microseismic monitoring results.



Multi-domain collaborative data integration display
(seismic, geologic, logging, fracturing and microseismic)

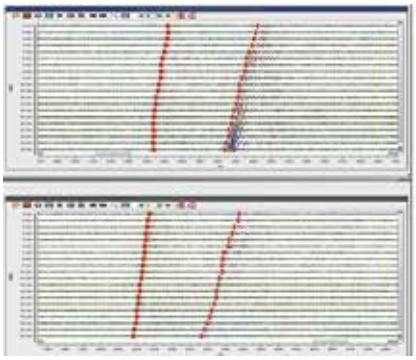
3 CHARACTERISTIC TECHNOLOGIES

◆Microseismic event identification and first break picking technology based on En-AIC

En-AIC method can identify microseismic events and carry out first break picking with high precision and high efficiency and can control picking of event signals of different energy levels according to thresholds.

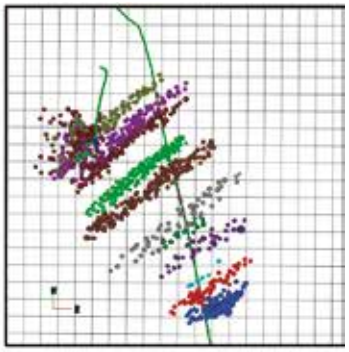
◆ Multi-constraint based microseismic event positioning technology

A comprehensive microseismic event positioning technology constrained by multiple parameters fully combines the characteristics such as microseismic first break, energy, polarization, etc. and mutually verifies and constrains them, thus finally obtaining the optimized seismic source space position.



Identification and picking of microseismic events of different energy levels with En-AIC method

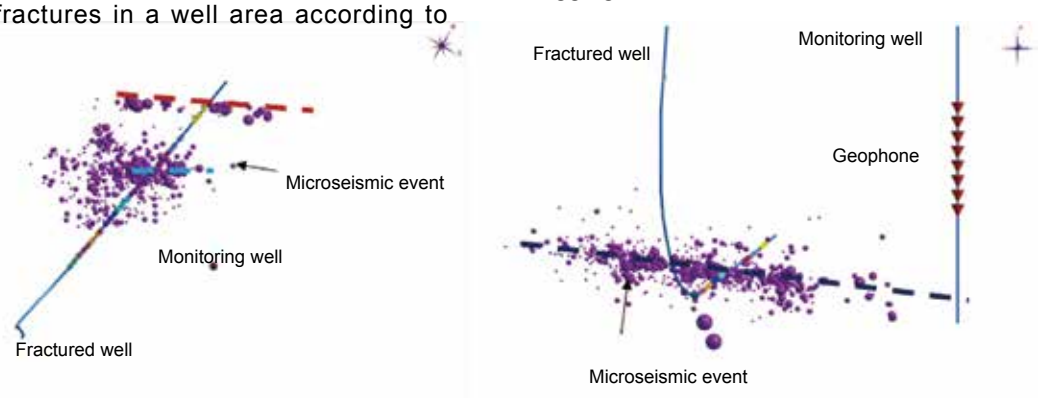
Top view of microseismic event positioning result of well N



Top view of microseismic monitoring of well HP

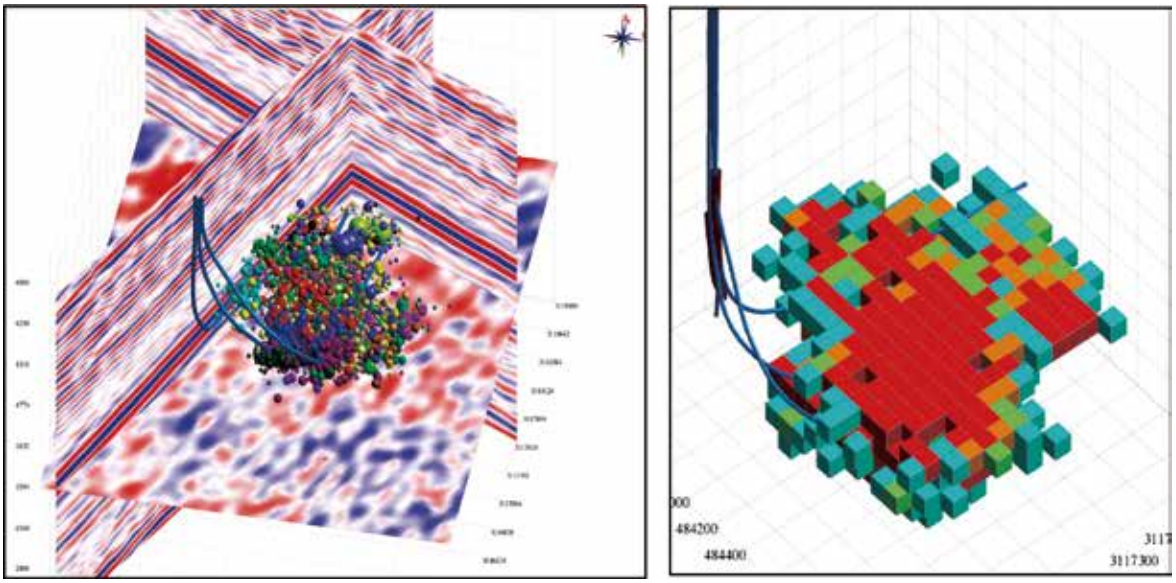
◆ Fracturing fracture net analysis and fracturing evaluation technology

Analyze the spatial distribution of main fracturing fractures, micro-fractures, secondary fractures and natural fractures in a well area according to the characteristics of microseismic event point sets involving time, space, earthquake magnitude, polarization, etc. as well as the direction of principal earth stress and the previous geologic, geophysical and logging results.



Fracturing fracture net analysis

The triangulation method is used to calculate the effective fracturing stimulation reservoir volume (SRV).

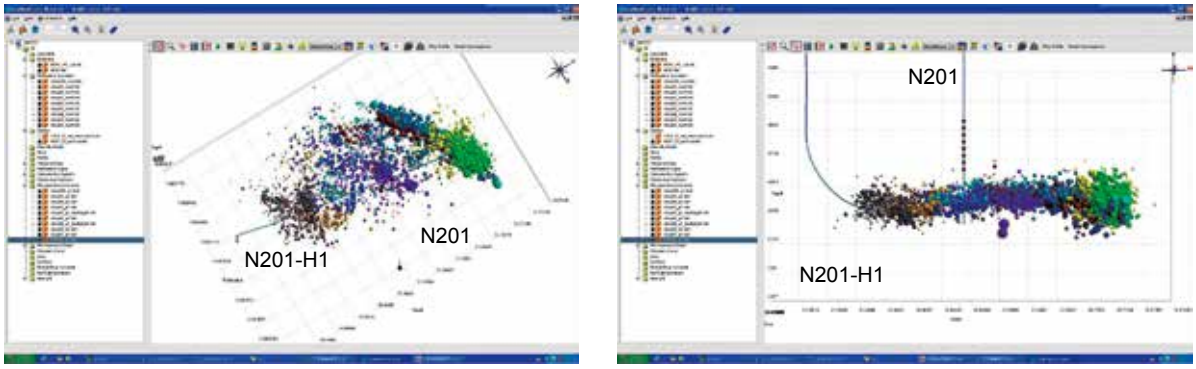


Microseism monitoring and SRV display of a well

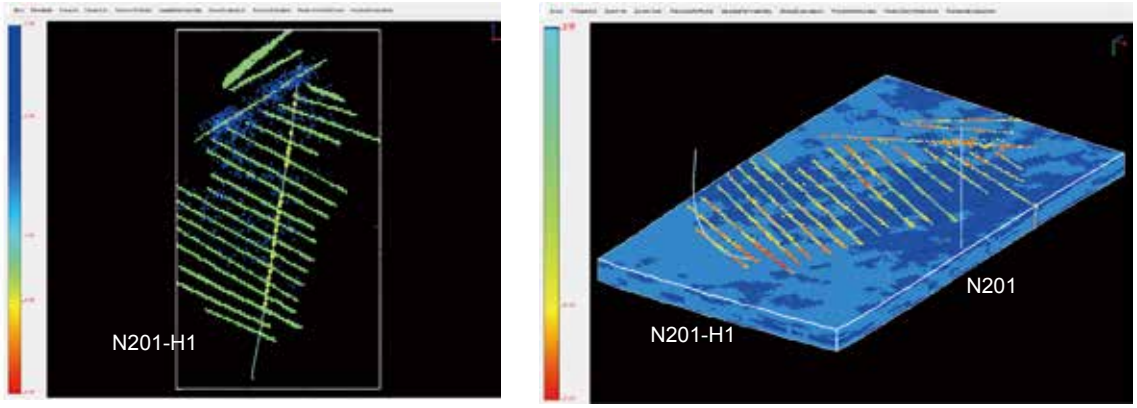
4 TYPICAL CASES

4.1 Microseismic deep well monitoring

Well N201 is located in Changning region, Sichuan. During fracturing of the well, low pressure and filling agent loss in large quantities occurred. Through real time site treatment with CQ-GeoMonitor® software system, there was a large scale natural fault in the fracturing area as determined. The software system provided real time guidance to fracturing operation parameter adjustment, thus avoiding fracturing risks very well. In addition, large-scope reticular fractures have been formed, and the gas production after fracturing has reached $14\times10^4 m^3/d$ AOF, thus improving fracturing quality and achieving a good reservoir stimulation effect.



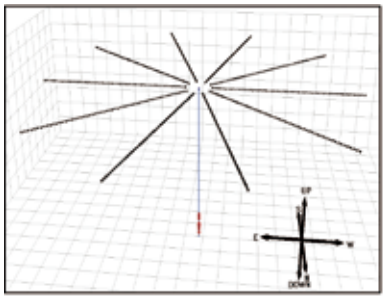
Microseismic deep well monitoring and positioning result of well N201-H1



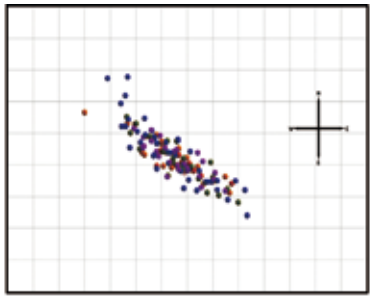
Comprehensive interpretation based on microseismic monitoring result
(Left: main azimuth calibration of blocky reservoir fractures;
right: updating of blocky reservoir permeability)

4.2 Microseismic surface monitoring

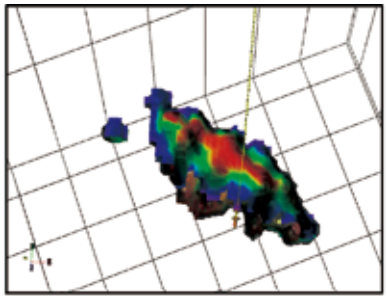
Well X03 is a vertical well. In order to generate sufficient percolation channels in target formation sandstones, the well was fractured in 5 sections. There was no monitoring well with an appropriate distance from well X03, so the fracturing effect was monitored using the microseismic surface monitoring method. CQ-GeoMonitor® software system of CNPC was used in real time monitoring of fracturing of the well. According to the monitoring result, the fracturing fractures in the well area are controlled mainly by stress direction and distributed in NW 60° azimuth, the length and width of the fracture net are 728m and 241m respectively, and M-SRV is $1184.8\times10^4m^3$, thus achieving the fracturing purpose.



Microseismic surface monitoring spread of well X03



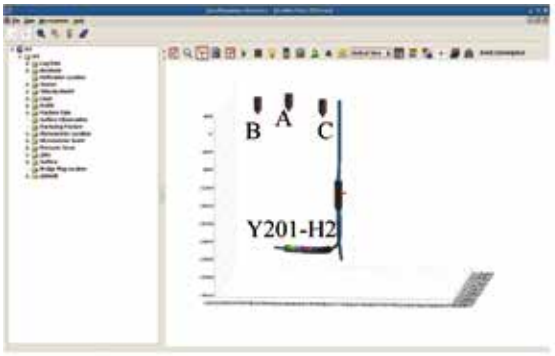
Top view of microseismic monitoring result of well X03



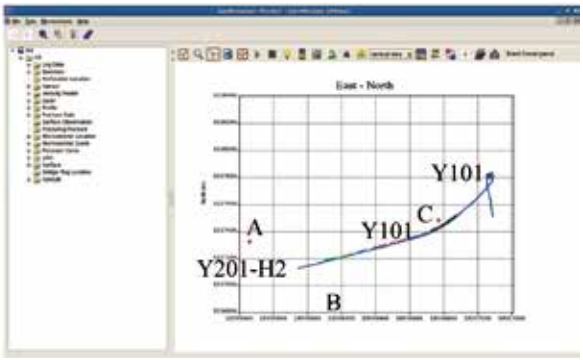
Fracturing fracture body of well X03

4.3 Microseismic joint monitoring involving “shallow well + deep well”

Well Y201-H2 is a horizontal shale well in Sichuan, with the horizontal section length of 1000m. To evaluate fracturing effect in real time and improve fracturing monitoring precision, the joint microseismic monitoring mode involving “3 shallow wells + 1 deep well” was used, as shown in the following microseismic geometry.



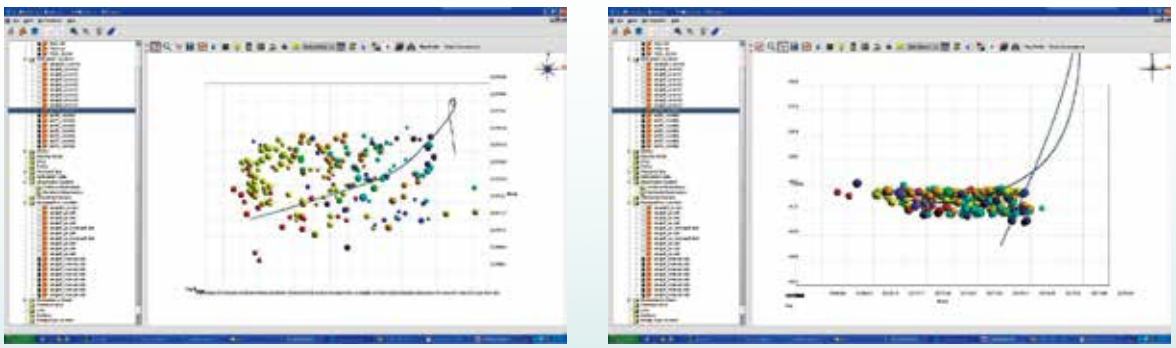
Side view of well Y201-H2 fracturing monitoring geometry



Top view of well Y201-H2 fracturing monitoring geometry

Recording instrument spread: 3 shallow wells + 1 deep well: 19-stage geophones for each shallow well and 40-stage geophones for the deep well; geophone spacing 15m.

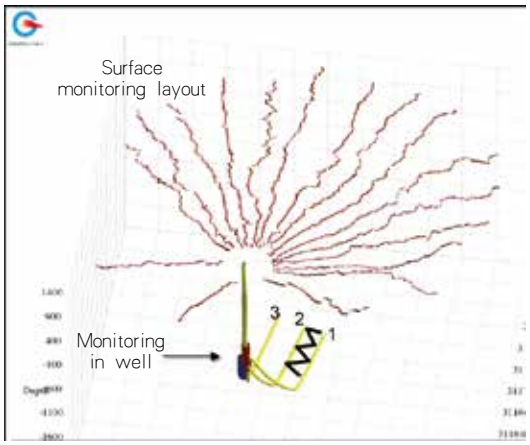
CQ-GeoMonitor® software system was in treatment involving perforation velocity correction, noise elimination, geophone azimuth correction, weak signal increasing, hypocentral location, etc. The system monitors microseismic events 33wm away from fracturing target formations in shallow well. According to the treatment result, the half-length and height of fracturing fractures of the well are 330~620m and 240m respectively, and SRV volume is $3300\times10^4m^3$. Complex fracture systems have been formed around the hole. The obtained daily shale gas production of the well is over 400000 m^3. The fracturing purpose has been achieved.



Microseismic monitoring and positioning result of well Y201-H2 fracturing

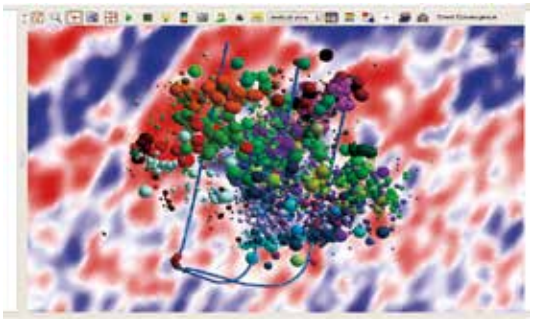
4.4 Microseismic joint monitoring involving “surface + deep well”

H3 platform project in “Sichuan Changning-Weiyuan national shale demonstration area” has totally 3 horizontal wells. To improve efficiency and precision, continuous industrialized zipper-type microseismic fracturing monitoring round the clock was firstly performed in China, and the joint monitoring mode involving “surface + deep well” was used. CQ-GeoMonitor® software system was used in real time monitoring of spatial distribution of fracturing fractures, thus providing real time guidance to fracturing operations, optimizing fracturing operation design and avoiding potential underground risks caused by fracturing operations.

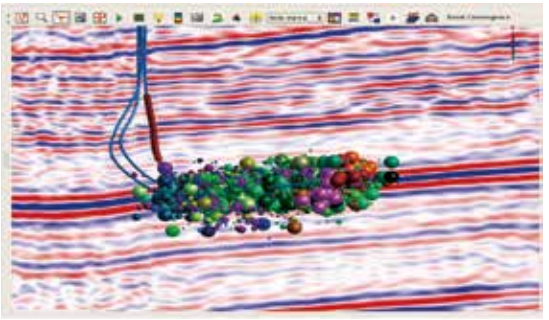


Monitoring in well and surface monitoring at the same time;
Surface monitoring: 17 spreads
(2425—channel geophones)
Monitoring in well: 3D grade geophones

Microseismic monitoring and observation parameters of H3 platform



Top view of microseismic monitoring of H3 platform



Side view of microseismic monitoring of H3 platform

5 SCIENTIFIC RESEARCH EQUIPMENT

The owned special equipment for microseismic monitoring: digital acquisition instruments for monitoring in well and surface monitoring acquisition systems; 105-stage acquisition equipment in well and 10000-piont digital geophones for surface acquisition; 50 pieces (sets) of GPS satellite orientators and total stations; 1 cable winch, 30 various engineering vehicles; 1 set of 300m shallow drilling equipment.

Hardware equipment

The largest computer center in the southwest region supports mountainous region seismic data processing and interpretation. The processing and interpretation computer cluster system has totally 4290 CPUs and 1505TB storage capacity as well as the independently developed CQ-GeoMonitor® microseismic monitoring software system. The center supports stand-alone environments such as various mainstream workstations, mobile PCs, etc. as well as large scale calculation environments including computer cluster systems etc. and can be used in field production as well as indoor fine processing and interpretation well.

Computer cluster

6 QUALIFICATIONS STANDARDS

CNPC Sichuan Geophysical Exploration Company (hereafter abbreviated to SCGC) is a professional company engaged mainly in mountainous region seismic exploration engineering services. SCGC has China “grade A mapping unit” qualification and has passed ISO9001:2008 international quality system certification. SCGC has established perfect environment management system and perfect occupational health and safety management system. SCGC has passed environment management system certification and CNPC HSE management system certification and has formulated or participated in multiple industrial and enterprise’s geophysical exploration technology standards.


质量管理体系认证证书


CERTIFICATE OF CONFORMITY OF QUALITY MANAGEMENT SYSTEM CERTIFICATION


环境管理体系认证证书


CERTIFICATE OF CONFORMITY OF ENVIRONMENTAL MANAGEMENT SYSTEM CERTIFICATION


职业健康安全管理体系认证证书


CERTIFICATE OF CONFORMITY OF OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT SYSTEM CERTIFICATION


测 绘 资 质 证 书

单位名称：

法定代表人：

业务范围：

等级及编号：

有效期至：

国家测绘局制

No.	Standard No.	Standard Name
1	SY-T 5314—2011	Technical specification for land petroleum seismic exploration data acquisition
2	SY-T 5171—2011	Specification for land petroleum geophysical survey
3	SY-T 5332—2011	Technical specification for land seismic exploration data processing
4	Q/SY 1116—2010	Technical specification for mountainous region seismic exploration data acquisition
5	Q/SY 1625—2013	Technical specification for microseismic monitoring in well
6	Q/SYCQZ 700—2013	Technical specification for inspection of GeoSpace GeoRes downhole seismic data acquisition system
7	Q/SYCQZ 701—2013	Standard operation procedure Microseismic surface monitoring operation
8	Q/SYCQZ 702—2013	Standard operation procedure Microseismic monitoring operation in well
9	Q/SYCQZ 692—2013	Technical specification for microseismic monitoring
10	Q/SYCQZ 688.2—2013	Technical specification for shale gas reservoir stimulation Part 2: microseismic monitoring
11	Q/SYCQZ 297—2013	Technical specification for seismic exploration data interpretation

No.	Patent name	Patent type	Application No. /patent No.	State
1	Analog inversion method for relative earthquake magnitude	Invention patent	201210424232.0	Handled
2	Microseismic monitoring and positioning method based on high-inclination well	Invention patent	201310330211.7	Handled
3	Surface microseismic positioning method based on 4D focusing	Invention patent	201210423976.0	Handled
4	Wave packet superposed microseismic surface positioning method	Invention patent	101310330555.8	Handled
5	An EnKF microseismic event positioning inversion method based on perforation constraint	Invention patent	201210313570.7	Handled
6	Pseudo-3D quick microseismic forward modeling method based on swept surface forward modeling	Invention patent	201210307813.6	Handled
7	Isotype wave time difference positioning method based on database technology	Invention patent	201110356935.X	Handled
8	P-wave and S-wave time difference positioning method based on database technology	Invention patent	201110356780.X	Handled
9	Microseismic event positioning method based on azimuth constraint	Invention patent	201210301342.8	Handled
10	A push device used to test microseismic geophones	Utility model patent	ZL201220633272.1	Authorized

7 AFTER-SALE SERVICES

User data model: CNPC builds user database and late-stage reservoir model to each fracturing monitoring user, provides dynamic simulation and establishes a fracturing monitoring parameter system for each production area.

Software upgrading: provide periodical software upgrading services and customize software modules according to the demand of different users.

Training: wholeheartedly provide professional training services for each CQ-GeoMonitor user.

Expert team: CNPC will provide you a professional fracturing monitoring expert team in each monitoring task.

Remote service team: provide remote services and timely solve your actual problems.

8 EXPERT TEAM

Li Yalin Natural gas exploration expert, member of SEG. He has been engaged in the study and application of petroleum geophysical exploration technology for many years. He has taken charge of completing over 20 national, provincial and ministerial projects involving microseismic monitoring, shale gas geophysical exploration, multi-component seismic exploration, fracture monitoring, etc. He was once awarded with “Fu Chengyi Youth Science and Technology Prize” of CGS and “The Seventh Youth Science and Technology Prize of Sichuan Province”. Over 80 papers written by him have been published. He has obtained 9 authorized invention patents.

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Wu Furong Microseismic monitoring technology expert. She has been engaged in the study and application of reservoir prediction, fracture detection and microseismic monitoring technology for many years. She has taken charge of completing over 20 national, provincial and ministerial projects involving microseismic monitoring, shale gas geophysical exploration, fracture monitoring, etc. She was once awarded with “The 16th Sun Yueqi Youth Science and Technology Prize” and “The 9th Youth Science and Technology Prize of Sichuan Province”. Over 30 papers written by her have been published. She has applied for 14 invention patents.

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He Guangming Seismic data processing and interpretation and integrated study technology expert. He has been engaged in the study of new theories such as wavelet theory, fractal theory, neural network, etc. for many years. He has taken charge of completing R&D and application of GeoMoutain complex mountainous region seismic software system and CQ-GeoMonitor microseismic monitoring software system. Over 30 academic papers written by him have been published. He has obtained over 20 authorized invention patents.

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Liu Hong Information engineering expert. He has been engaged in seismic data processing method research and software development for many years. He has participated in provincial and ministerial R&D projects many times. He has taken charge of R&D and application of CQ-GeoMonitor microseismic monitoring software system. 6 academic papers written by him have been published. He has obtained over 10 authorized invention patents.
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Cao Libin VSP and microseismic monitoring technology expert. He has been engaged in the study of VSP technology, microseismic fracturing monitoring technology and well control seismic data processing technology. He has completed multiple provincial, ministerial and bureau level projects. Over 10 papers written by him have been published. He has applied for 3 invention patents.
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Email: caolibin_sc@cnpc.com.cn

Yin Chen Microseismic monitoring technology expert. She is engaged in microseismic monitoring technology R&D and software development. She has completed multiple provincial, ministerial and bureau level microseismic monitoring technology research and application projects. She was once awarded with the title “Top 10 Outstanding Youth Science and Technology Workers” of Chuanqing Drilling Engineering Company Limited. She has participated in international conferences many times. Over 10 papers written by her have been published. She has applied for 9 invention patents.
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Kang Liang Microseismic monitoring technology expert. He has completed the study of multiple microseismic monitoring technologies and made multiple technical breakthroughs in microseismic monitoring acquisition design, processing, interpretation, etc. Over 10 papers written by him have been published. He has applied for 9 invention patents.
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中国石油

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Tel: 86-10-59986059/59982528

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