

GeoSeisQC Field Seismic Acquisition Quality Monitoring System

Science & Technology Management Department, CNPC

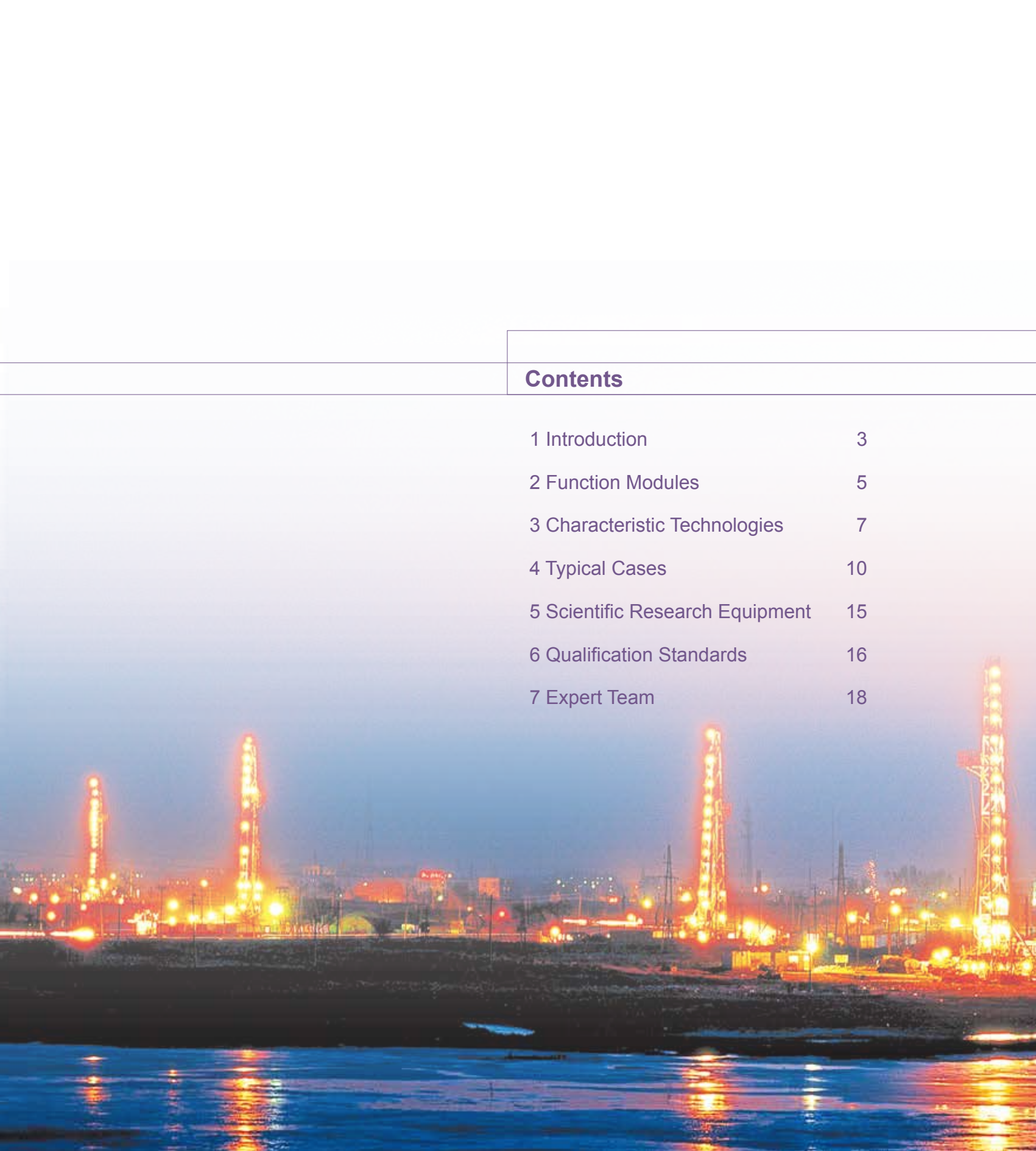
2015



CHINA NATIONAL PETROLEUM CORPORATION

*To Improve Seismic Data Quality, Starting
with Field Seismic Acquisition Quality
Monitoring System!*





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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 reorganized 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.

The GeoSeisQC field seismic acquisition quality monitoring system is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

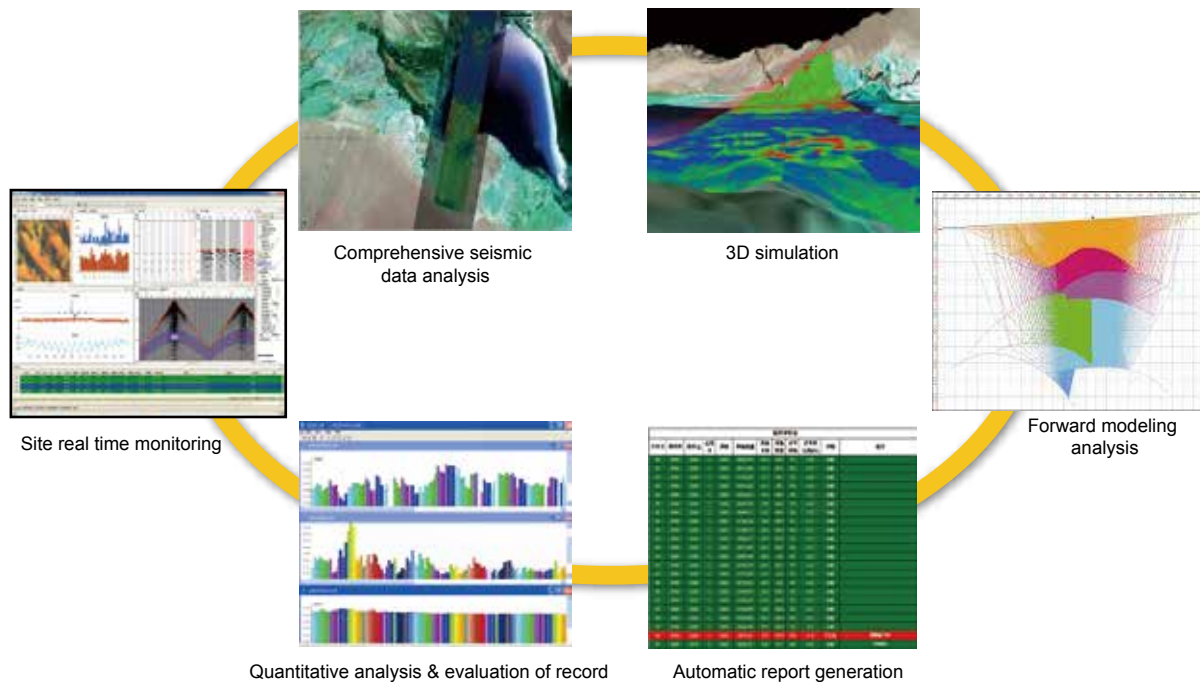
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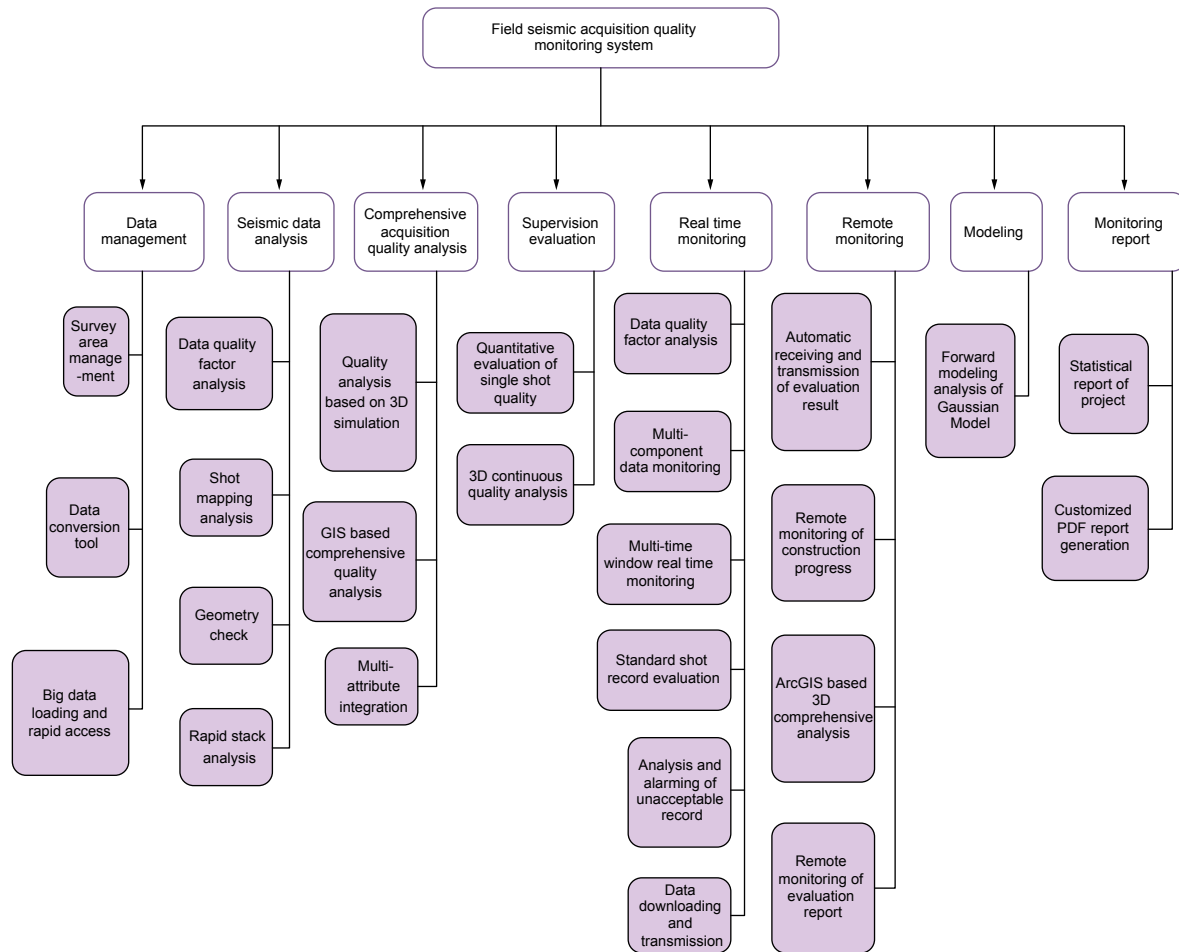
INTRODUCTION

“GeoSeisQC field seismic acquisition quality monitoring system” is a comprehensive field acquisition quality monitoring and intelligent analysis system composed of field real time monitoring, comprehensive laboratory analysis and network-based seismic quality evaluation with regard to the problem on qualitative analysis of field acquisition quality monitoring by experience for long. High-efficiency software tools have been provided for purposes of realizing normalization and quantification of field seismogram analysis and evaluation, improving field seismic acquisition quality and a uniform seismic exploration data acquisition quality

evaluation specification.

“GeoSeisQC” provides core functions such as real time shot quality analysis of seismogram, auxiliary data analysis, geographic information evaluation, 3D simulation and quantitative analysis of seismogram quality, automatic monitoring and evaluation of seismic data, comprehensive analysis, remote network monitoring, etc. based on field operation data and seismic acquisition data. “GeoSeisQC” provides users technical means for comprehensive analysis and evaluation of seismic data acquisition quality, including field, laboratory and remote analyses.





“GeoSeisQC Field Seismic Acquisition Quality Monitoring System” provides core functions such as real time shot quality analysis of seismogram, auxiliary data analysis, geographic information evaluation, 3D simulation and quantitative analysis of seismogram quality, automatic monitoring and evaluation of seismic data, comprehensive analysis,

remote network monitoring, etc. It’s based on field operation data and seismic acquisition data, thus meeting the needs of different user layers for field acquisition quality monitoring data management, data quality analysis, operation quality monitoring, quantitative evaluation, result report, etc.

2 FUNCTION MODULES

2.1 Data management

Support multiple data formats, provide convenient and quick data conversion tools, and highly effectively input and output seismic acquisition data with multi-threads. Provide users comprehensively optimized data management solutions.

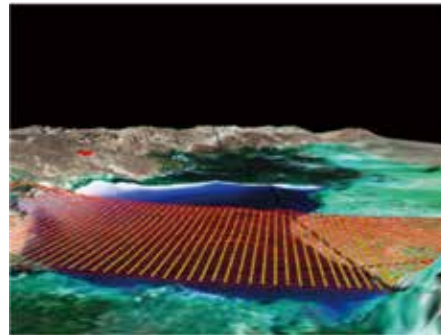
2.2 Seismic data analysis and auxiliary data analysis

Seismic data analysis: based on data analysis, quick stack analysis, static correction analysis and site data analysis, realize comprehensive quantitative analysis of various gather attributes of seismic data and provide quick and effective means for users to analyze record quality.

Auxiliary data analysis: provide powerful tools for users to verify and check the physical point location of data, calibrate geometry, and analyze folds, surface layer conditions and drilling conditions.

2.3 3D simulation

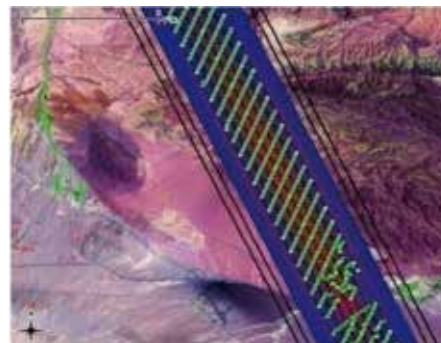
Build the 3D visual image of the target survey area and reproduce the 3D space features of the target survey area based on digital elevation model and remote sensing image spectrum information, so that users analyze and study the target survey area as a whole more intuitively and comprehensively.



3D simulation

2.4 Comprehensive seismic data analysis

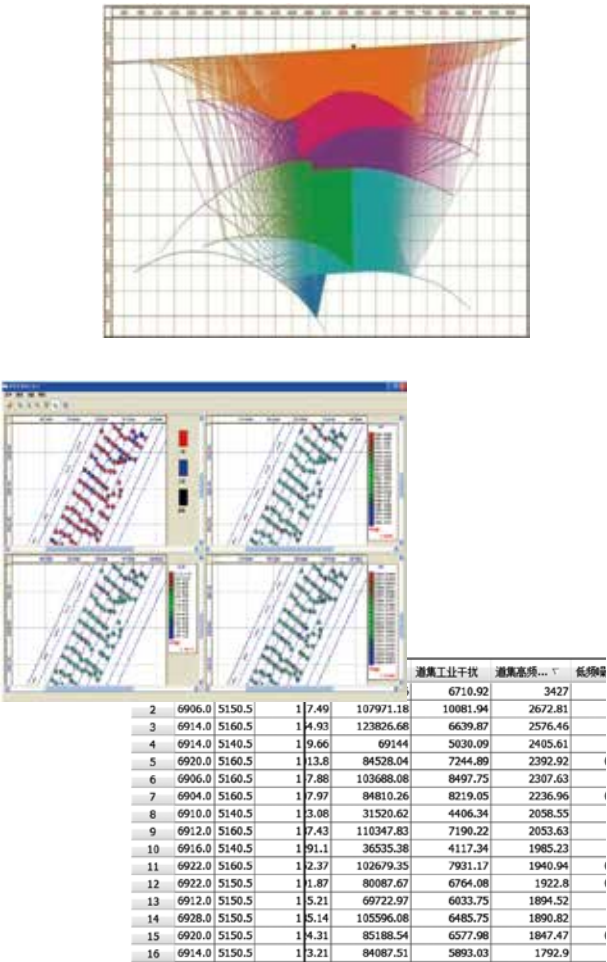
Realize the function of display and analysis of various data including survey area based map, topographic map and other datas based on GIS; comprehensively analyze and display the survey area according to seismic operation survey net data, satellite photos, surface and operation information and system calculation and analysis information; provide plentiful data interfaces and query and measurement function.



Comprehensive seismic data analysis

2.5 Forward modeling analysis

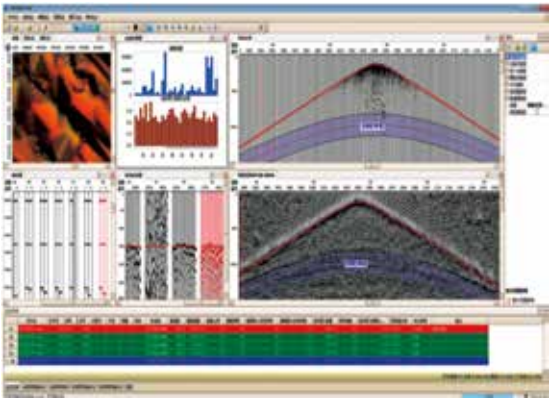
Carry out ray tracking of the model using the “Gaussian ray bundle” method and simulate the model’s seismic response, so that users can observe the situation of arrival of each reflection wave group at the receiving domain below the inclined interface.



Forward modeling analysis of seismic model

2.6 Site real time monitoring

Provide a uniform connection solution to various instruments. Carry out site real time data analysis of quality monitoring key factors such as target formation energy, frequency, SNR, etc.; quantitatively monitor site signal quality, analyze a shot after acquisition of a shot, and reduce record replay cost and time; quantitatively analyze and evaluate operation quality more reasonably in the mode of standard shot.

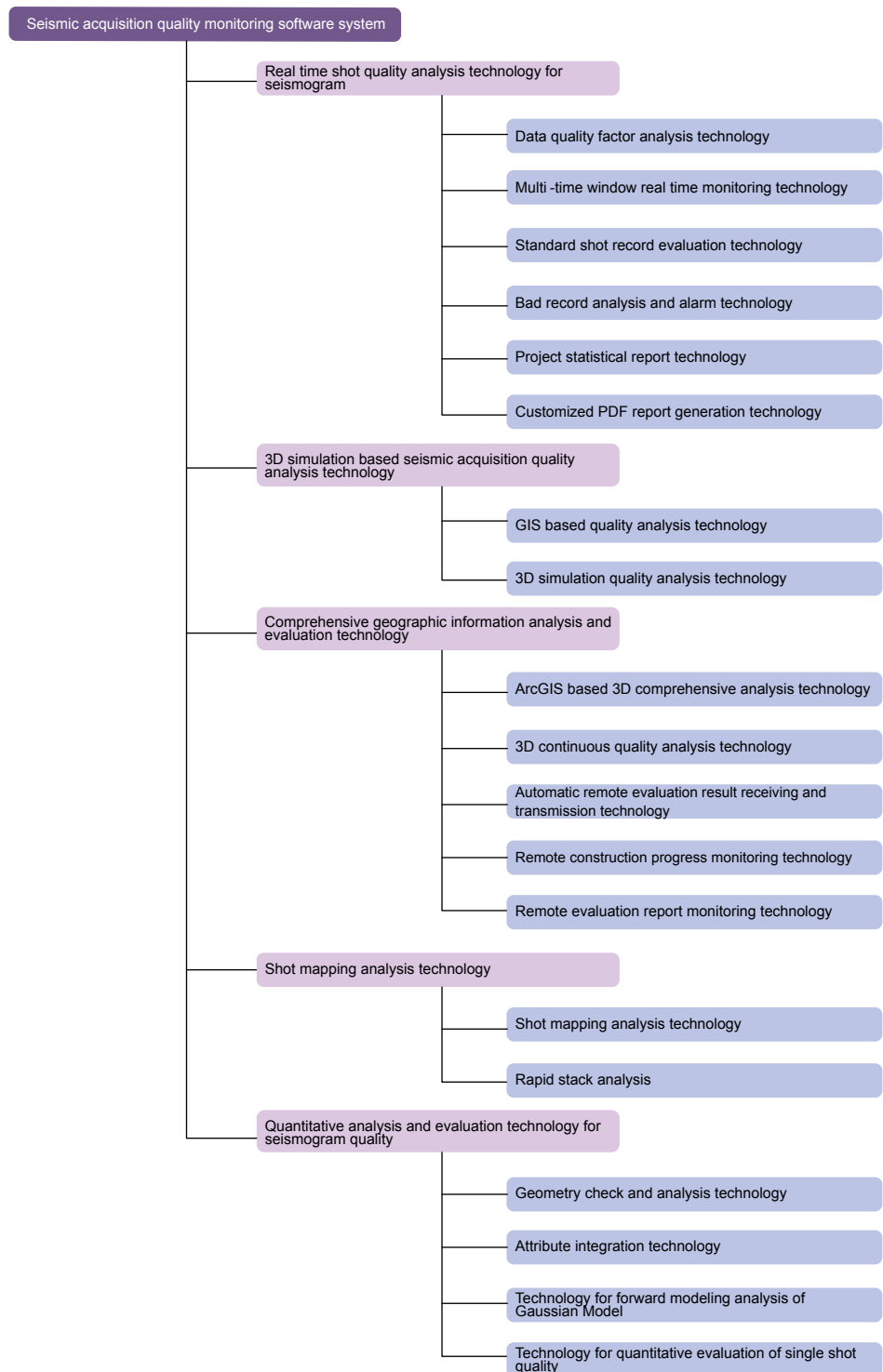


Site real time monitoring

2.7 Quantitative supervision evaluation and automatic report generation

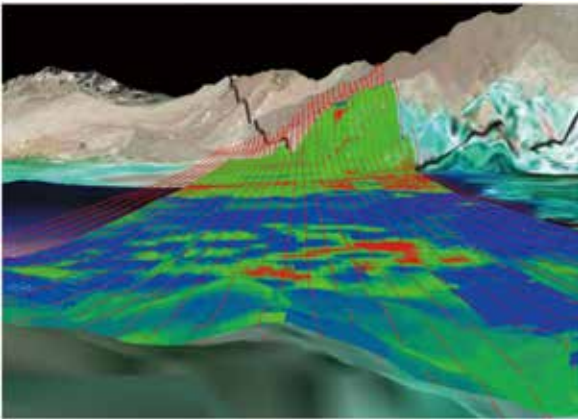
Various factors affecting data quality including interference, SNR, energy, resolution, excitation frequency, abnormal value, auxiliary channel and other things can be analyzed as needed by users. According to threshold value evaluation data quality, the data generated in the analysis process can be customized and evaluated by users. A supervision evaluation report is generated via report wizard.

3 CHARACTERISTIC TECHNOLOGIES



3.1 3D simulation based quality analysis technology

Combine digital elevation model with remote sensing image spectrum information using QGIS technology, build the 3D visual image of the target survey area, reproduce the 3D space features of the target survey area, and reveal the shot distribution law in the whole survey area. According to 3D satellite photos and images, conveniently determine the influential factors of surface conditions for shot quality and then determine whether shot quality reduction is due to human factors or objective factors accurately, thereby quickly working out the acquisition operation scheme and improving field seismic data acquisition quality monitoring level.

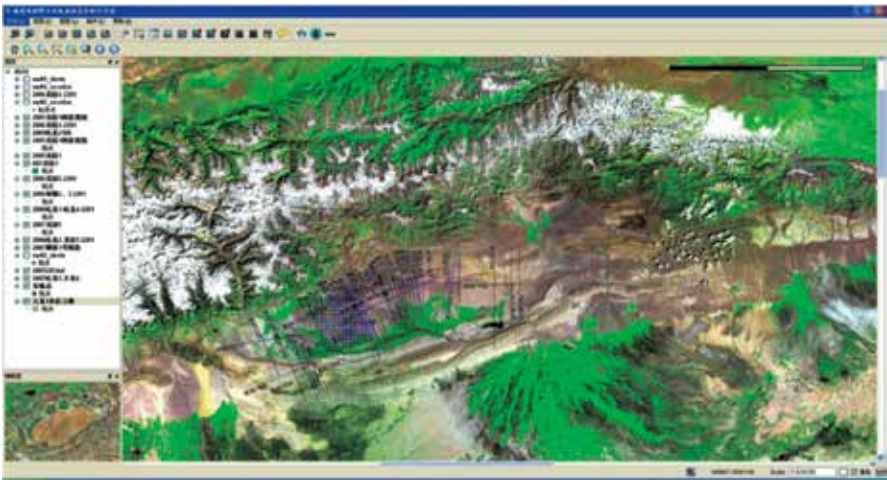


3D simulation of shot energy

3.2 GIS based comprehensive seismic acquisition analysis technology

Use the GIS technology, integrate all sorts of geographic information, remote sensing data and various acquisition quality monitoring and analysis

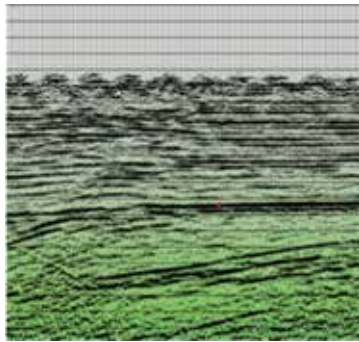
results, and thus realize whole-area monitoring of field seismic acquisition quality. Reveal the whole seismic acquisition situation in the whole survey area, avoid the sense of easy direction loss under 3D visual conditions, and improve field acquisition quality monitoring efficiency and precision.



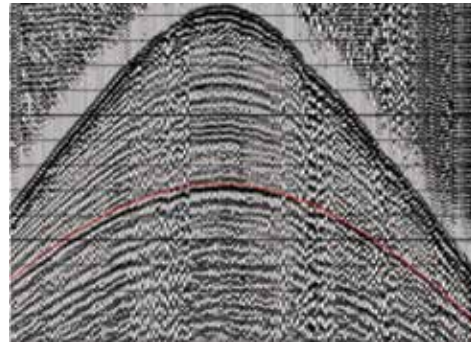
GIS based acquisition quality analysis

3.3 Shot mapping analysis method

Beginning with original single shot record, organically combine stacked profile with shot record through prestack and poststack interaction analysis and quick stack calculation and then check the reflection wave of the “target formation”. The reliability of seismic data processing can be quickly judged, and the problem on quantitative analysis and objective evaluation of field seismic acquisition data in complex regions can be solved.



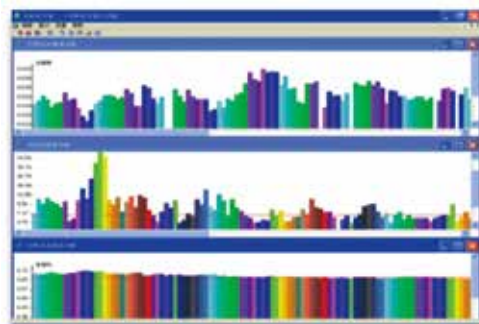
Quick stack profile



Mapping of single shot record

3.4 Quantitative seismic acquisition quality evaluation technology

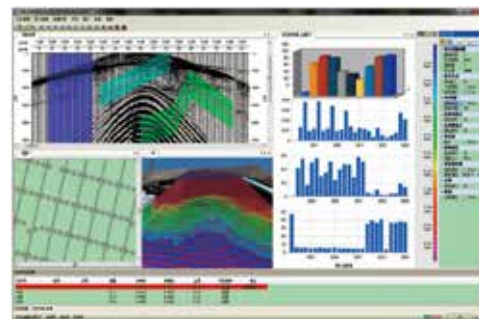
Automatically carry out quantitative analysis and evaluation of seismogram according to the previously analyzed and formulated evaluation standard on the basis of analysis of noise interference, abnormal channel, gather attribute, etc. Realize qualitative conversion of traditional qualitative analysis of seismogram quality with direct sensory into normalized and quantitative high-efficiency analysis.



Energy, SNR and resolution analysis

3.5 Real time shot quality analysis technology for seismogram

Build an uniform seismic acquisition instrument data platform. The platform is fitted with an uniform data reading interface for seismic acquisition instruments and quickly analyzes the key factors for affecting acquisition quality shot by shot in real time.



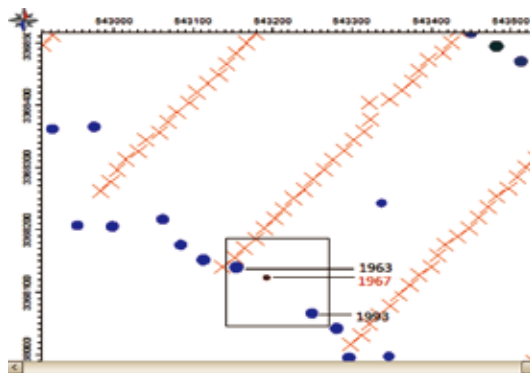
Real time shot quality analysis

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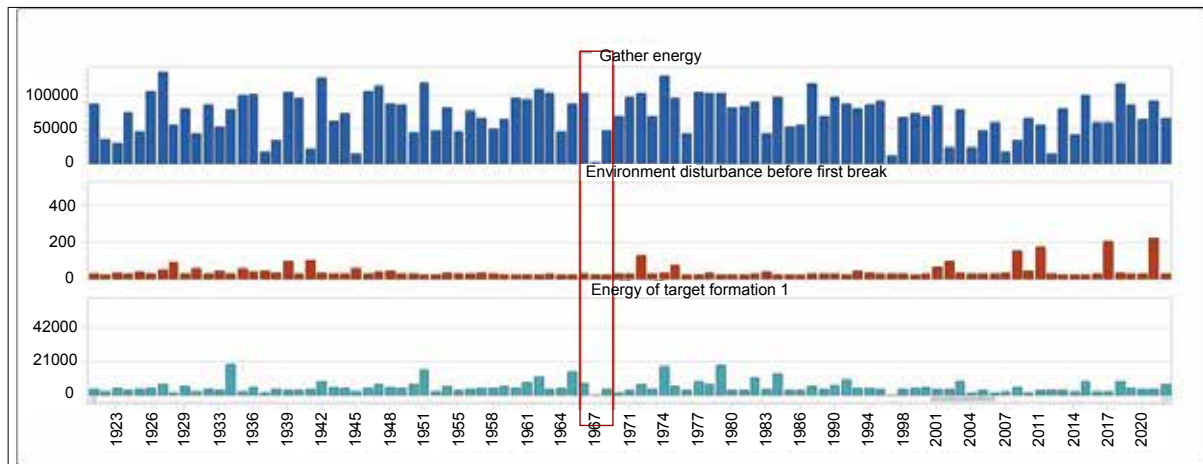
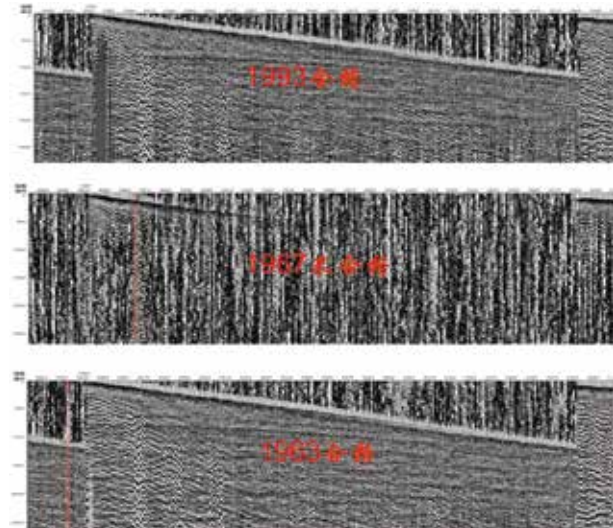
TYPICAL CASES

4.1 ZG8 3D survey area

The problem on large difficulty in original single shot quality control in ultra-large spread seismic acquisition was solved during 3D comprehensive high-density acquisition in ZG8 3D survey area, thus greatly improving monitoring efficiency by around 10 times and monitoring scientificity.

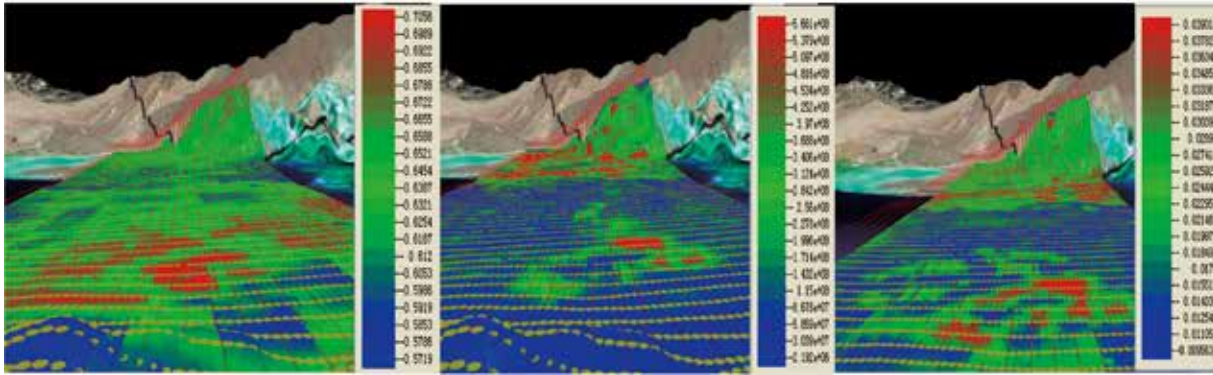


Quickly and visually show unacceptable seismograms using base maps (the size of dot) and histograms (high and low).



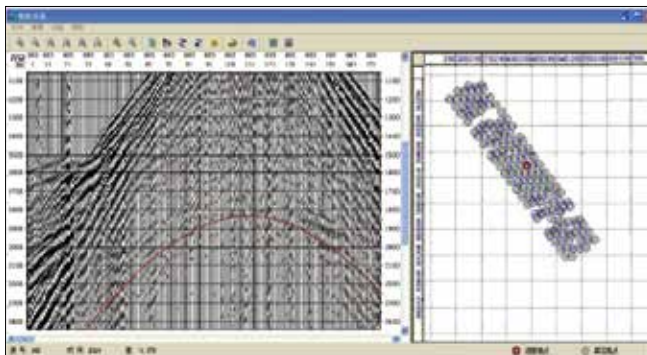
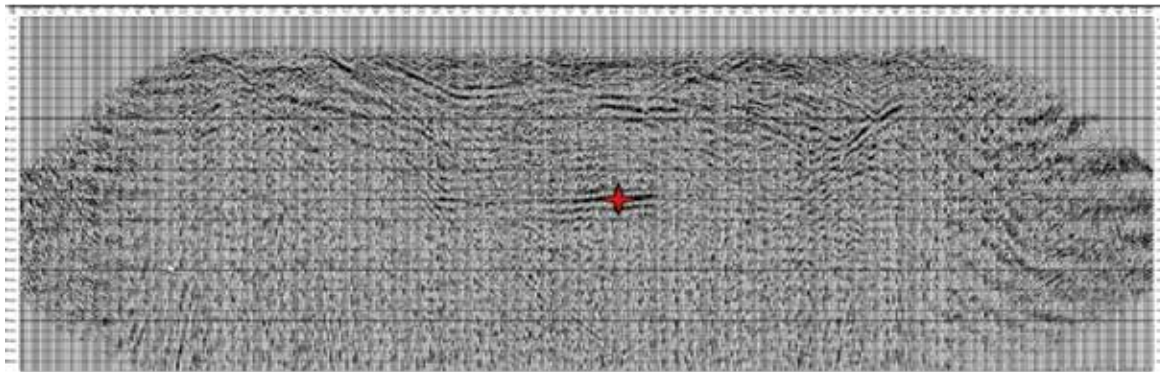
Monitor the quality factors such as gather energy, target formation energy, etc. from multiple aspects quickly and visually. This is more visual. The result is more reliable.

Make a systematic analysis of the integral distribution of topography, landform, energy, SNR and resolution of the whole survey area using the 3D simulation technology. According to the analysis result, lake surface has relatively weak energy in general and relatively strong energy, which conforms to actual land surface conditions.



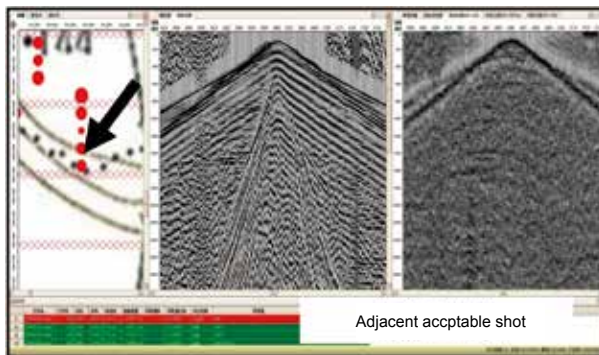
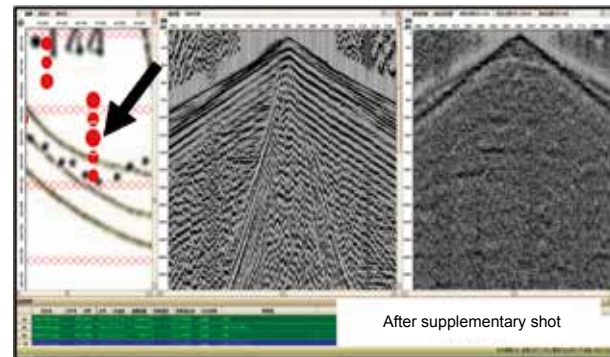
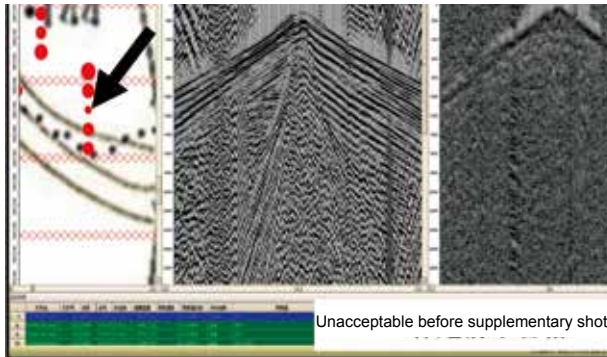
4.2 Huabei L18 well 3D survey area

The survey area crosses towns, random and fixed interference is serious, and artificial monitoring is difficult. The field seismic acquisition quality monitoring system analyzes the key factors such as energy SNR for deciding record quality and improves the quality and efficiency of quality monitoring.



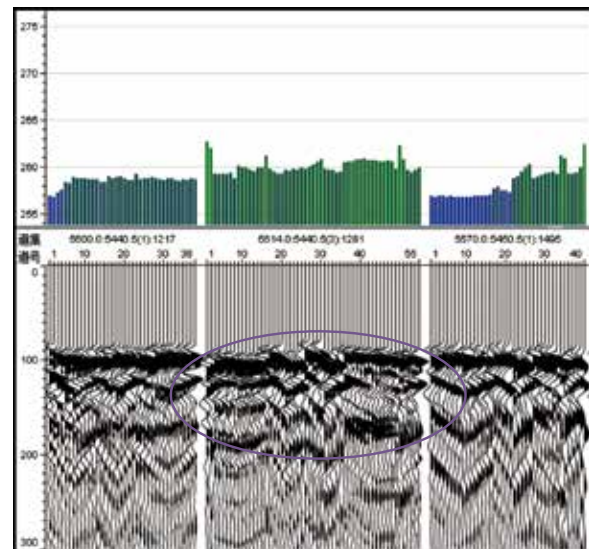
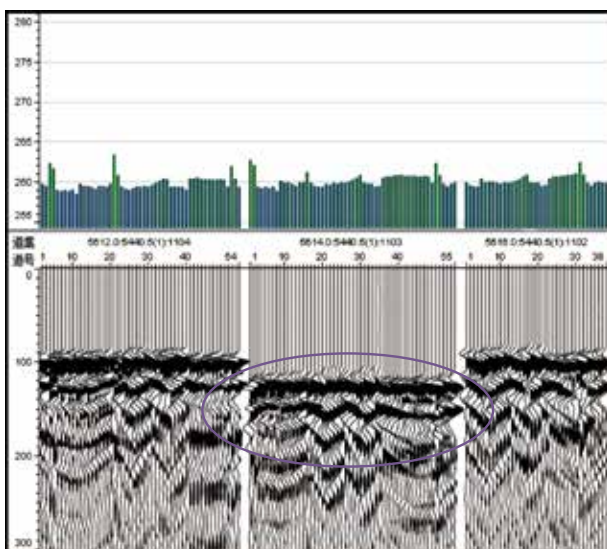
Carry out filtering of single shot record to remove random noise; perform prestack preprocessing including deconvolution etc., carry out quick stacking, make a comprehensive analysis of single shot physical point location and original single shot record; accurately analyze the reflection information on target formation.

TYPICAL CASES



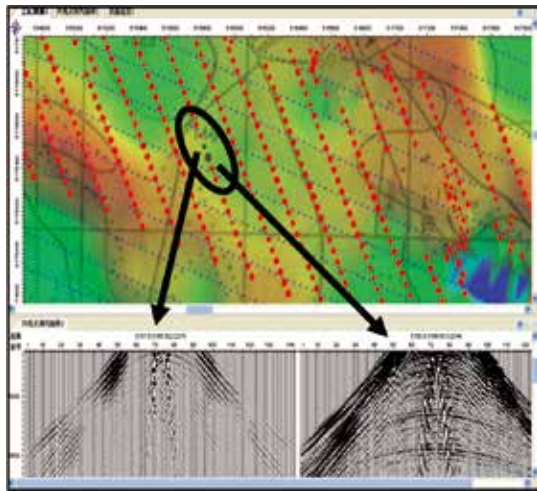
Carry out real time monitoring, find quality problems and take remedy measures in time using the check means such as energy, point location delay, etc.

For instance, timely find that a shot has weak energy and low sweep frequency. Compared with adjacent single shots, the shot has bad quality obviously. A notice is given on supplementary shot. The single-shot sweep frequency after supplementary shot reaches requirements.

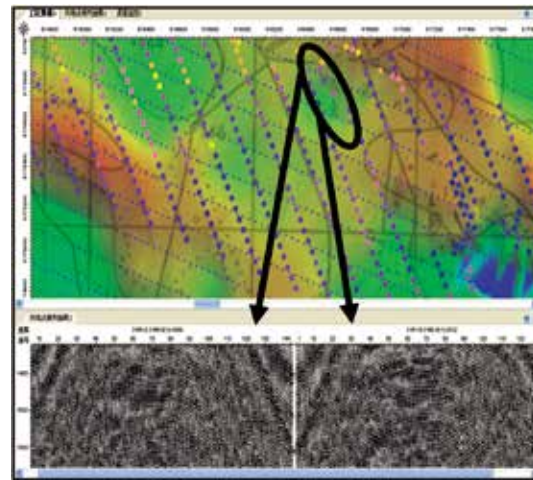


4.3 Application in Southwest Oil and Gas Field

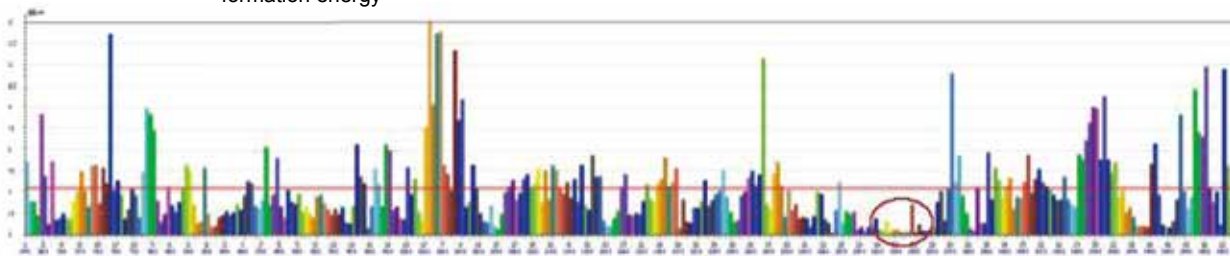
The system has been successively used in the survey areas including natural gas development 3D survey area in Daxingchang buried structure in Sichuan basin, Penglai south-Gaoshiti south multi-wave 3D survey area, etc. The survey areas include multiple complex land surface conditions such as mountainous regions, swamps, etc. The system has been used to carry out analysis and evaluation of different areas, thus greatly improving monitoring efficiency.



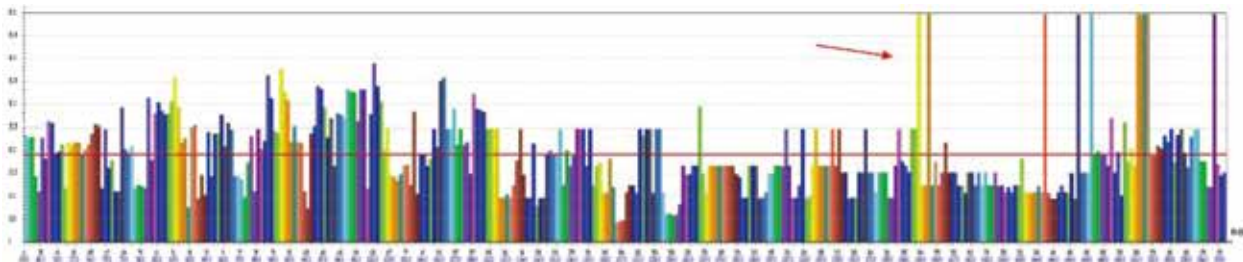
Elevation based excitation energy analysis
Different shot sizes represent the intensity of target formation energy



Elevation based excitation frequency analysis
Different shot colors represent the magnitude of the highest dominant frequency of target formation

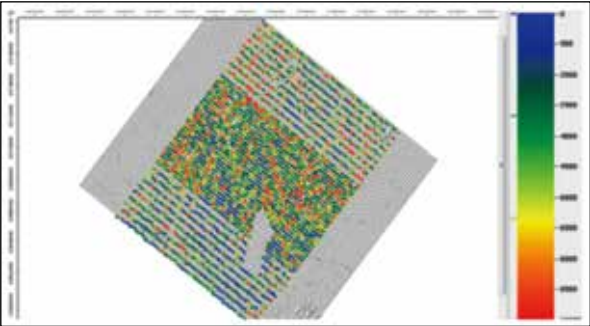


Shot energy diagram of a line; bench gravel section recording weak energy

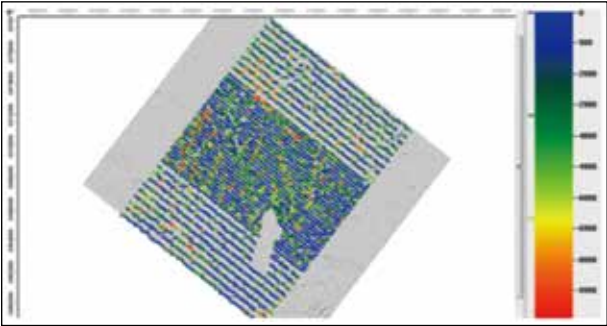


The main frequency diagram of a line; the main frequency 50Hz means the shot disturbed seriously by external high voltage power

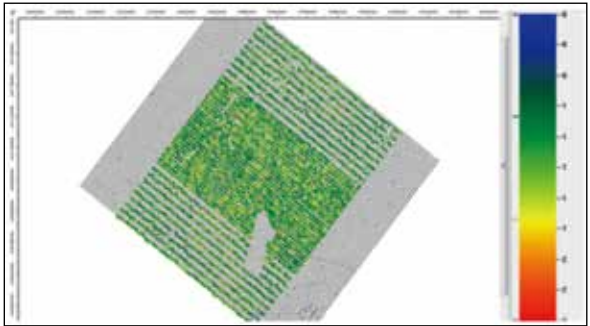
Form the planar analysis chart of the target formation energy, SNR, etc. of the whole survey area through target formation calculation as per the data of different components. Through comparative analysis, users can understand the overall operation quality of the survey area easily.



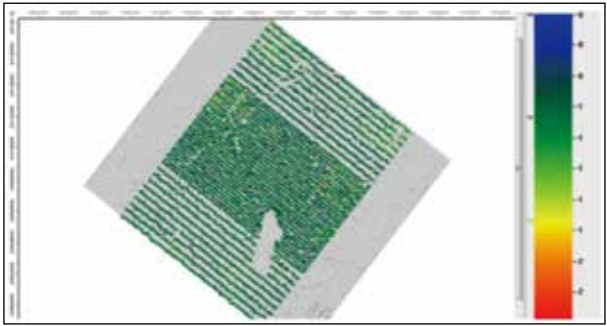
Z-component bundle target formation energy



X-component bundle target formation energy



Z-component bundle target formation SNR



X-component bundle target formation SNR

4.4 Other regions

The system has been applied in 23 projects in oilfields such as Daqing, Southwest, Tarim, Xinjiang, etc. (17 3D survey areas, totaling 7300km²; 6 2D survey areas, totaling 2060km²), and totally over 687000 shots have been monitored.

Exploration area	Project name	Exploration area	Instrument type	Standard shot setting item
Chuanqing oil field	Moxi-Longnvsi 3D in Sichuan basin in 2013	2087km ²	428XL	Mainly increasing gather energy and checking abnormal channels
	Tieshan-Shuangjiaba block 3D in Longgang east region in Sichuan basin in 2013	636.6km ²	428XL	
Tarim oil field	3D in Shenmu region, Kuqa depression in 2013	262km ²	428XL	Mainly increasing gather energy
	3D in Tuziawate region, Kuqa depression in 2013	231.9km ²	428XL	
	Luonan 3D in Tarim basin in 2013	116.3km ²	scorpion	
Xinjiang oil field	Duimahu-1 3D in 2014	403.92km ²	428XL	SNR, background interference, energy
	Dinan-8 3D in 2014	595.3km ²	428XL	SNR, gather energy

5 SCIENTIFIC RESEARCH EQUIPMENT

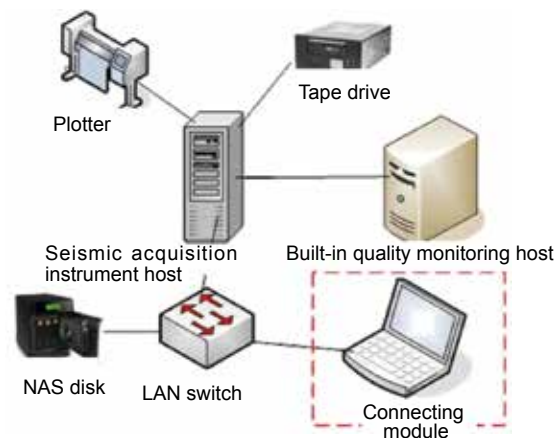
5.1 Hardware equipment

CNPC has reservoir description key laboratory and geophysical key laboratory, GPU processing system with 60 nodes and 110000 cores, PC-Cluster computer cluster with 4000 CPUs and 1460TB storage equipment. CNPC has several all-in-one machines and mobile workstations for GeoSeisQC site monitoring.



5.2 Software equipment

CNPC has remote seismic acquisition quality monitoring servers which automatically receive and forward single-shot quality analysis and evaluation results supplied to the management department of Party A to carry out remote real time analysis and monitoring of site equality. CNPC has database servers for data storage and evaluation result storage. CNPC has the currently mainstream seismic acquisition instrument modules which are compatible with the currently mainstream seismic acquisition instruments.



6 QUALIFICATION STANDARDS

6.1 Standards

Standards

The standards and specifications followed in system development cover petroleum enterprise standards involving seismic data acquisition, acquisition site processing, data format definition, etc.

《SY/T 5314—2011 Technical Code for Seismic Data Acquisition》

《SY/T 6052—2000 Technical Code for Seismic Exploration Data Acquisition and Site Processing》

《SY/T 6290—2011 Format of Auxiliary Data of Land 3D Seismic Exploration》

《Q/SY 52—2007 Technical supervision and acceptance code for seismic acquisition engineering quality》

《QSHQ185.2—2008 Technical Code for Seismic Data Acquisition》

《SY/T 6290—2011 SPS format of auxiliary data of seismic exploration》

《SY/T 6391—1999 SEG-D seismic tape record format》

《QCNPC 51—2001 Technical specification for land 2D seismic exploration data acquisition》

《SY/T 5455—1997 Technical specification for land 3D seismic exploration data acquisition》

Standards formulated

Technical Specification for Real Time Monitoring and Quantitative Evaluation of Seismic Acquisition Data Quality of CNPC has been formulated based on the evaluation parameters and evaluation process of the system. A series of acquisition quality monitoring operation has been normalized, including single-shot quality analysis and evaluation, parameter optimization, etc. A digital seismic acquisition quality monitoring industrial new mode has been originated. The development of field seismic acquisition technologies of CNPC has been powerfully supported.



6.2 Software copyrights

9 national software copyrights have been obtained:

Seismic data acquisition quality monitoring software system V1.0

Seismic data acquisition quality monitoring software system V2.0

Seismic acquisition quality monitoring, real time analysis and evaluation system V1.0

Seismic exploration data management system V1.0

Field seismic data acquisition site processing system V1.0

Field seismic acquisition surface layer forward modeling system V1.0

Real surface 3D simulation based seismic acquisition quality analysis system V1.0

GIS based seismic acquisition quality evaluation system V1.0

Field seismic acquisition quality monitoring and evaluation system V1.0



6.3 Patents

3 national patents have been obtained:

GIS based comprehensive seismic acquisition quality analysis and evaluation method ZL 2010 1 0553707.7

3D real surface simulation based field seismic acquisition quality monitoring technology ZL 2010 1 Q588367.1

Shot stack mapping based seismic acquisition quality analysis technology ZL 2010 1 0548313.2



7

EXPERT TEAM



Wang Xiwen

Senior technical expert, professor level senior engineer, doctor. He is mainly engaged in technical research on seismic wave propagation theory and application, wavelet analysis, fine reservoir prediction, effective identification of lithologic traps, etc. He has obtained 4 grade I provincial and ministerial science and technology advance prizes, 1 grade II provincial and ministerial science and technology advance prize, 7 grade I bureau level science and technology advance prizes and 4 grade II bureau level science and technology advance prizes. 1 monograph and 58 academic papers written by him have been published.

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Yong Xueshan

Senior technical expert, professor level senior engineer, doctor. He is mainly engaged in reservoir prediction and oil and gas detection technology research. He has obtained 1 national invention patent and declared for 1 national invention patent. He has obtained 2 grade I provincial and ministerial science and technology advance prizes, 2 grade II provincial and ministerial science and technology advance prizes and 8 grade I bureau level science and technology advance prizes. Over 30 papers written by him have been published at WPC, SEG Annual Conference and various academic conferences or in journals.

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**Yang Wuyang**

Technical expert, senior engineer, doctor, the member of SEG and CPS. He is mainly engaged in method research and software development in the fields involving seismic wave propagation theory, prestack inversion, fine reservoir prediction, oil and gas prediction, etc. He has obtained many innovative achievements in prestack/poststack seismic inversion, reservoir parameter estimation, seismic attribute analysis, non-conventional reservoir description, preserved-amplitude prestack depth migration, etc. He has obtained 2 grade I science and technology advance prizes of Gansu Province. Over 50 academic papers written by him have been published.

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**Gao Jianhu**

Technical expert, doctor, senior engineer, the member of CPS. He is mainly engaged in the study of two-phase medium high precision reservoir imaging and fluid imaging methods as well as the application study of well constraint inversion, transverse reservoir prediction and prestack inversion. He has obtained 2 grade I provincial and ministerial science and technology advance prizes and 4 grade I bureau science and technology advance prizes. Multiple papers written by him have been published.

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Xu Yongze

Technical expert, senior engineer. He is mainly engaged in R&D of geosciences application software involving seismic data processing, database development and application, oil and gas monitoring, reservoir detection, software integration technology, etc. He has successively obtained 1 grade I provincial science and technology advance prize, 2 grade II ministerial prizes, 3 grade I bureau level prizes and 2 grade II bureau level prizes. Multiple papers written by him have been published.

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Zhang Qiaofeng

Technical expert, senior engineer. She is mainly engaged in seismic data processing, seismic reservoir inversion, full 3D visual interpretation, geosciences software testing, etc. She has participated in seismic inversion work in key blocks of oilfields including Daqing, Changqing, Qinghai, Tarim, Junggar, Sichuan, Nanhai, Venezuela, etc. She has obtained 1 grade II ministerial prize. Multiple papers written by her have been published.

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**Zhou Chunlei**

Technical expert, senior engineer. He is mainly engaged in R&D of geophysical forward modeling and inversion theory, seismic data processing software, oil and gas detection, reservoir prediction, software integration technology, etc. He has obtained 1 grade I science and technology advance prize of Gansu Province, 2 grade II ministerial prizes, 5 grade I bureau level prizes and 6 grade II bureau level prizes. Multiple papers written by him have been published.

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**Wei Xinjian**

Technical expert, master, software engineer. He is mainly engaged in R&D of seismic acquisition software. He has proposed innovative methods for improving mass data access efficiency, mainstream seismic instrument connection technology, 3D geographic information technology, comprehensive evaluation of seismic data acquisition quality, etc. He was responsible for software architecture design, base layer data module development work, etc. in the project. He has obtained 1 grade III science and technology advance prize of Gansu Province and 1 grade II ministerial prize. Multiple papers written by him have been published.

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