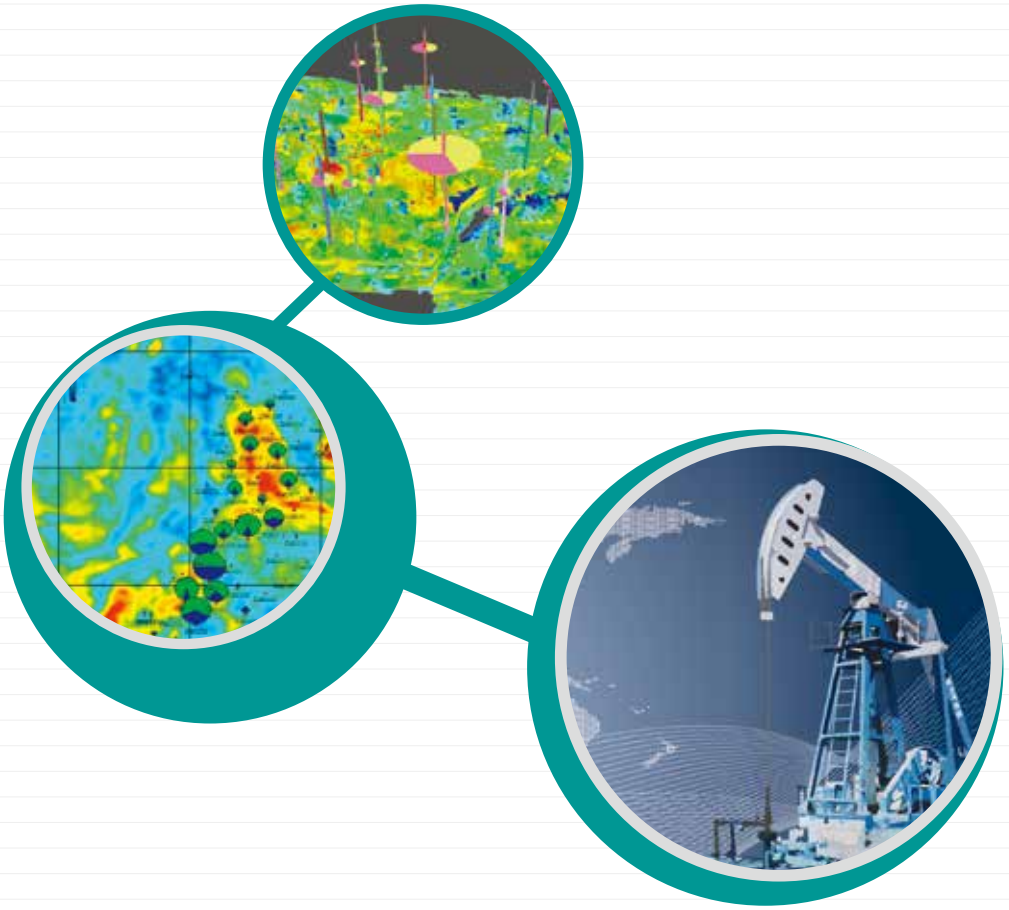
GeoEast-RE Comprehensive Reservoir Geophysics Evaluation System

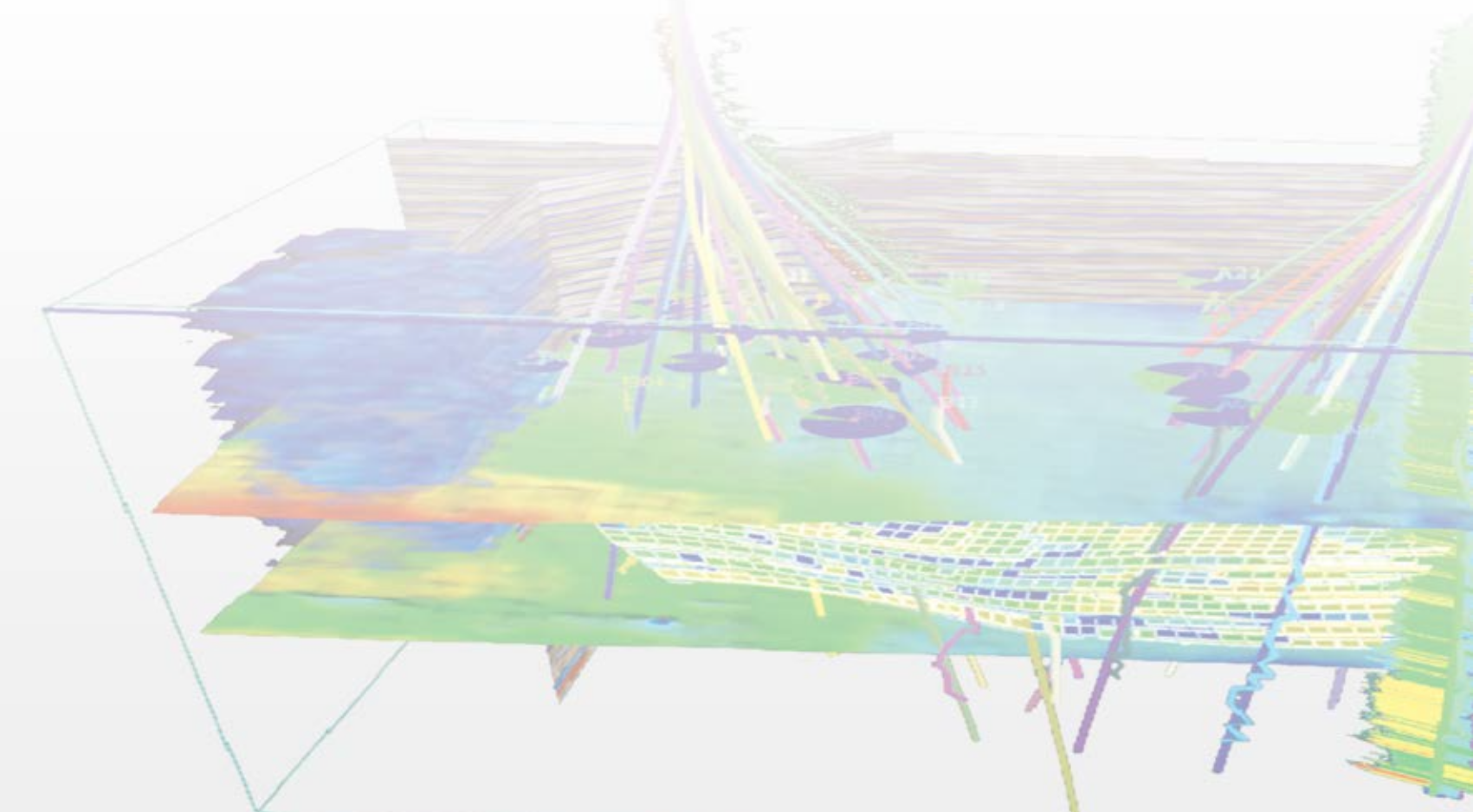
Science & Technology Management Department, CNPC

2015



CHINA NATIONAL PETROLEUM CORPORATION

GeoEast-RE : Opening Underground Labyrinths, Searching Remaining Oil and Gas!



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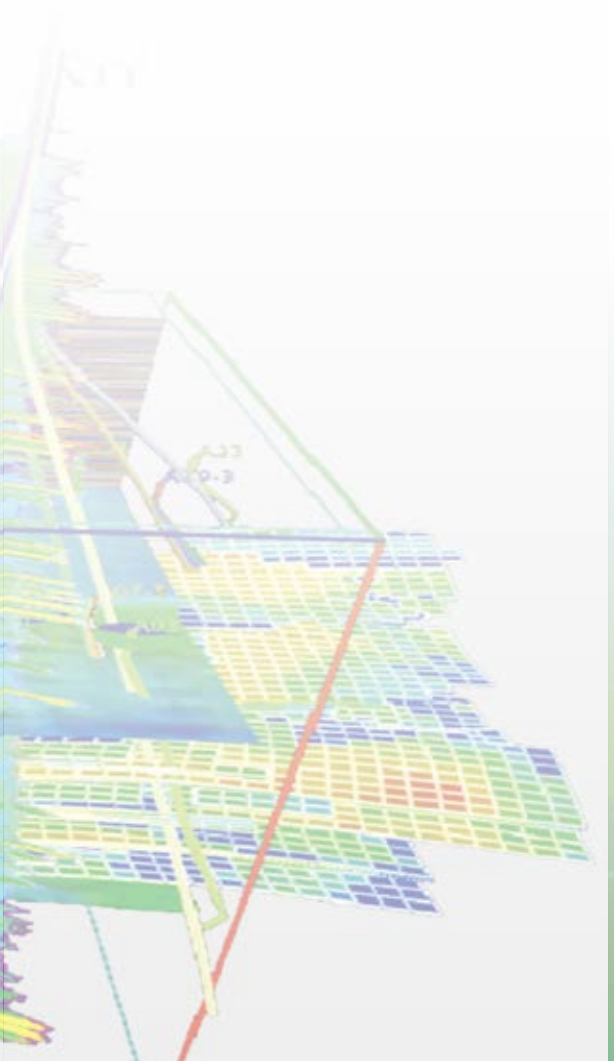


China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. On July 1998, with the implementation of the Institutional reform of the State Council, CNPC was reorgnized to become an integrated oil company of cross-regions, cross-industries and cross-countries, 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.

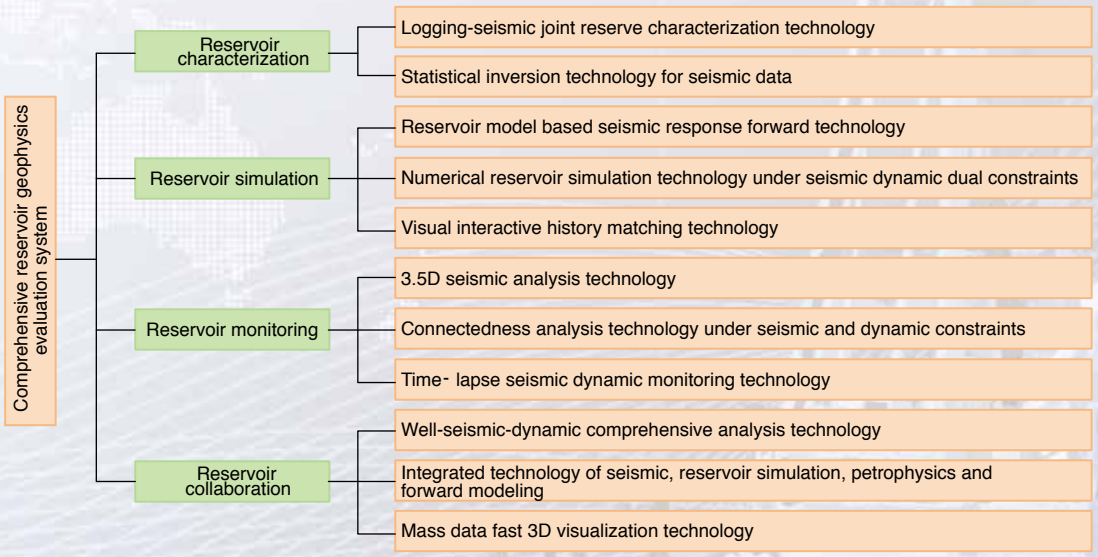
GeoEast-RE comprehensive reservoir geophysics evaluation system is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

1 INTRODUCTION

Focusing on complex reservoir problems, GeoEast-RE comprehensive reservoir geophysics evaluation system integrates multidisciplinary information involving seismic information, petrophysical information, logging information, VSP information, sedimentation information, inversion information, non-seismic information and reservoir development information, is intended to carry out reservoir characterization, reservoir detection and reservoir simulation as well as multidisciplinary collaboration, and provides an important tool and a technical support to determining remaining oil distribution and EOR as well as effective means for seismic extension to reservoir development. The system has the following main features:

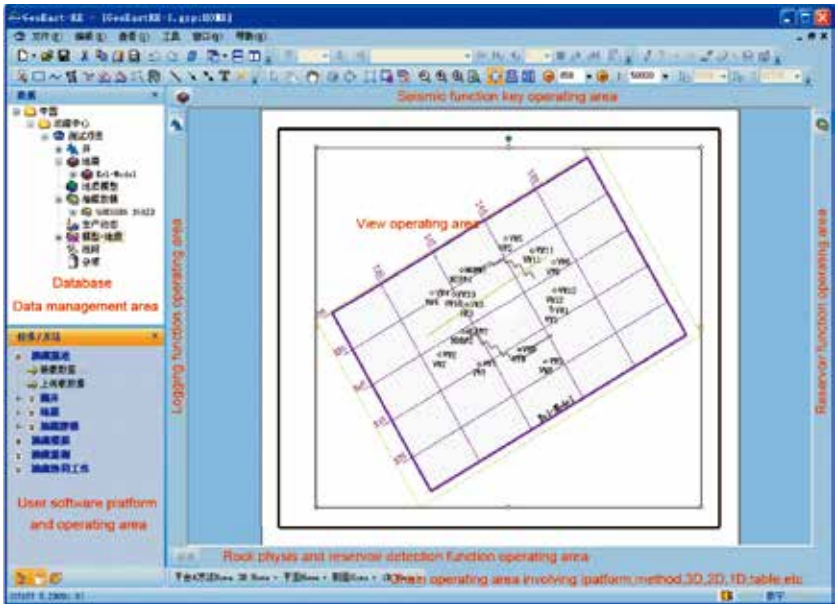
- Comprehensive system with integrated reservoir engineering and seismic technology
- Main means of seismic services for development
- High-efficiency tool for recognition of geologic and dynamic laws based on geologic and seismic data
- Characteristic tool for analyzing remaining oil and gas based on seismic data
- Brand-new chain data analysis mode to make 3.5D seismic analysis convenient and quick



GeoEast-RE technology framework

2 MODULE FUNCTIONS

GeoEast-RE uses the development idea of geographic coordinate plane whiteboard interface + chain display+ multi-methods + multi-industry function key interface, and each subsystem uses the working environment design idea of the identical design interface, process flow and function, thus forming the comprehensive reservoir geophysics software platform with independent intellectual property rights involving reservoir characterization software subsystem (RC), reservoir simulation software subsystem (RS), reservoir monitoring software subsystem (RM) and reservoir integrated collaboration subsystem (RI).

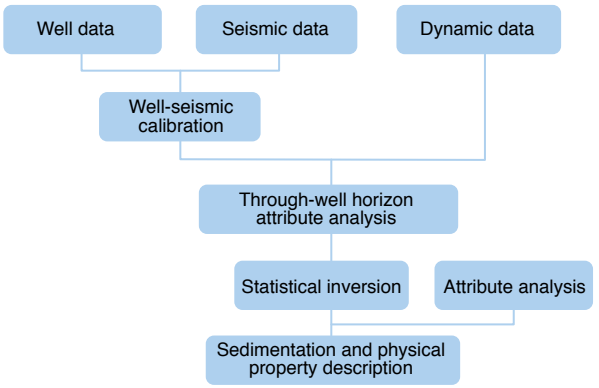


GeoEast-RE Operation Interface

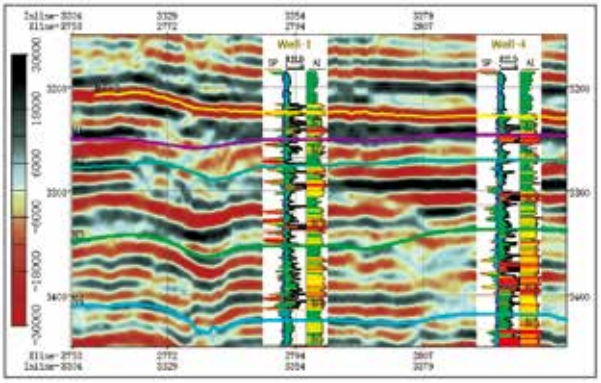
Through tight combination of geophysics and reservoir engineering in data and model domains, reservoir geophysics engineers can carry out reservoir characterization and research with the software, recognize reservoir geology and establish a preliminary reservoir geology model by combining well data with seismic data; reservoir engineers can carry out numerical reservoir simulation and dynamic analysis with the software. Reservoir geophysics engineers and reservoir engineers can carry out seismic data interpretation and analysis, inversion and 4D feasibility study under reservoir background using the software, further interpret seismic attributes and analyze spatial reservoir potential and determine the remaining oil and gas distribution of reservoirs based on dynamic information.

2.1 Reservoir Characterization Subsystem (RC)

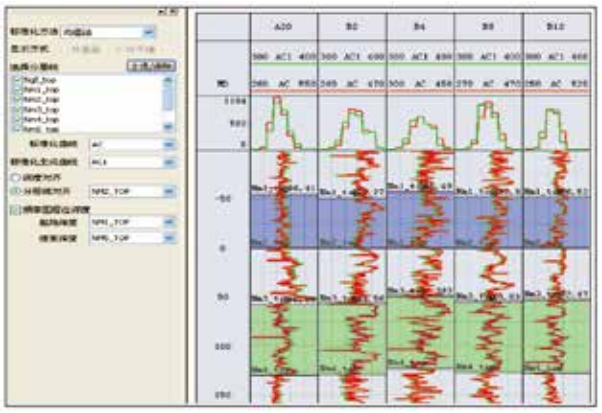
Carry out well-seismic calibration, combined well-seismic stratigraphic correlation, sequence analysis, structural interpretation and sedimentary facies analysis using logging, seismic and geologic materials; perform reservoir prediction, reservoir space distribution research and evaluation, physical property prediction and oil and gas detection using multiple methods (attribute analysis, well-seismic inversion); analyze oil and gas distribution law and simplify reservoir geology models; provide guidance to reservoir characterization comprehensively using logging information and seismic information.



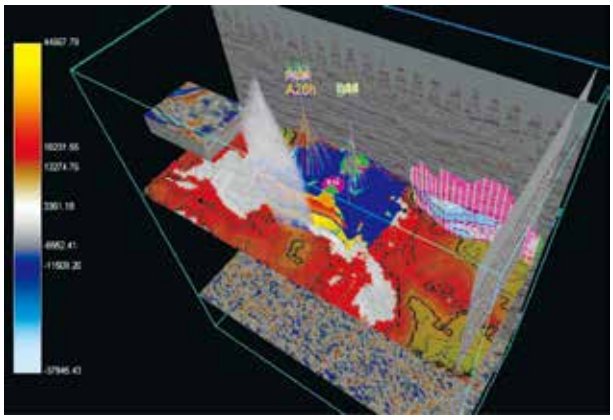
Technical flow chart of reservoir characterization subsystem



Well-Seismic combined stratigraphic correlation profile



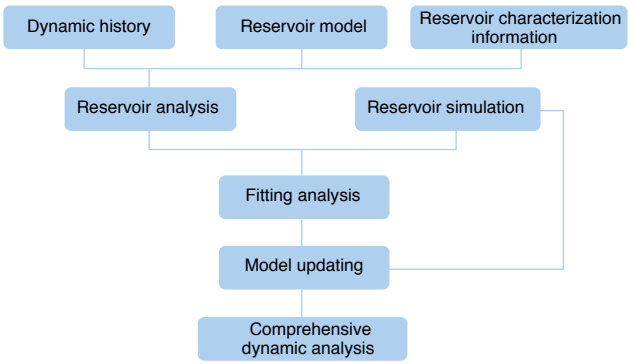
Logging data standardization chart



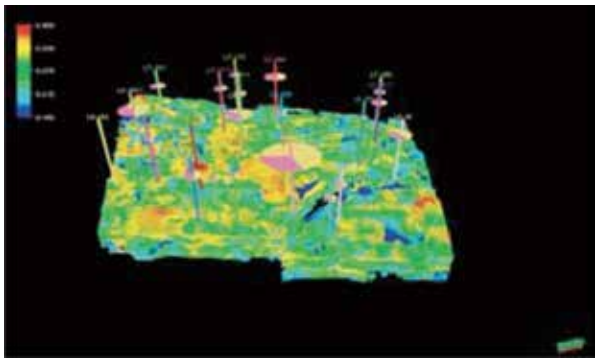
Seismic and logging multi-data 3D display graph

2.2 Reservoir Simulation Subsystem (RS)

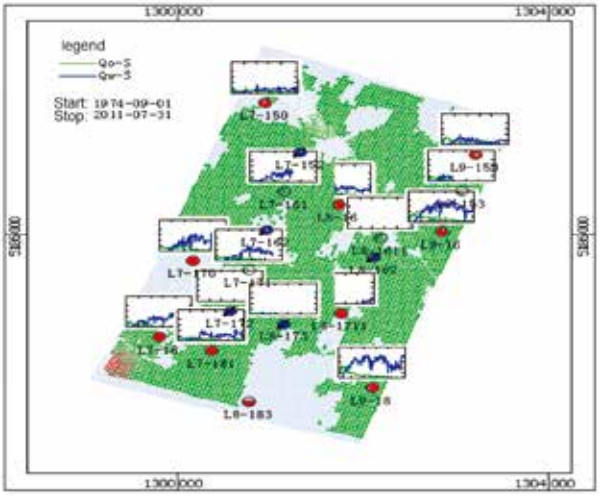
The subsystem includes the two parts such as processing before and after numerical reservoir simulation. The subsystem can be used to carry out visual analysis and interactive modification of numerical reservoir model data, start numerical simulation operation, load numerical simulation results, make a fitting error space analysis and quickly localize error objects and supports Eclipse, CMG, VIP, etc. The subsystem can make fitting results more reasonably through seismic attribute constraint during history matching.



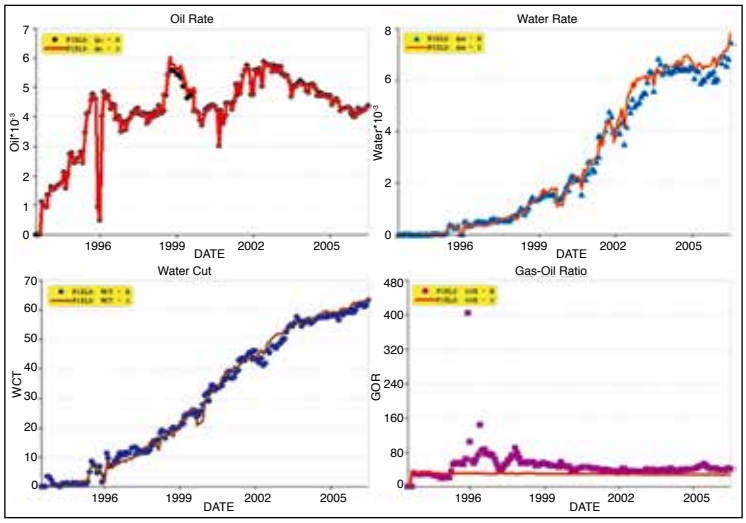
Technical flow chart of reservoir simulation subsystem



Dynamic parameter and bubble chart 3D display



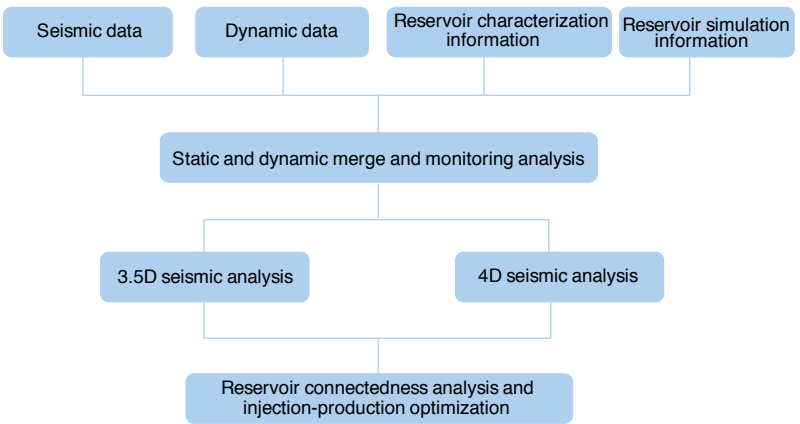
Plane distribution diagram of well history data



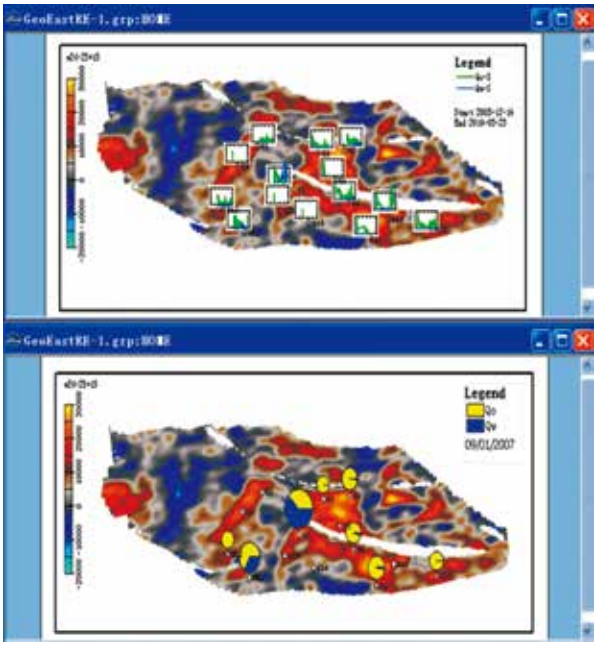
History matching curve comparison chart

2.3 Reservoir Monitoring Subsystem (RM)

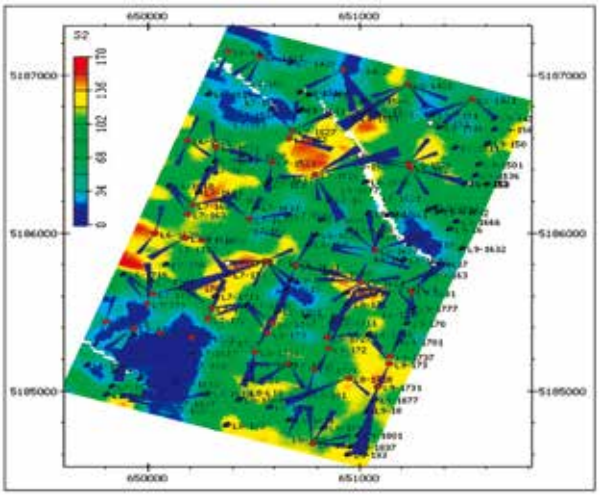
Realize quick visual analysis and calculation of injection-production data of wells; carry out connectedness calculation and analysis, 3.5D seismic analysis, time-lapse seismic dynamic monitoring analysis constrained by seismic attribute data; study remaining oil and gas distribution law and search potential areas. The main functions of the subsystem include: dynamic data management and visualization, connectedness analysis constrained by well performance data, 3.5D comprehensive seismic analysis tools, time-lapse dynamic monitoring and analysis tools, etc.



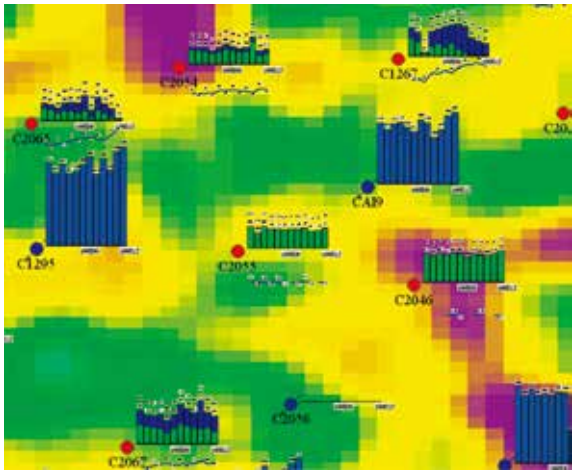
Technical flow chart of reservoir monitoring subsystem



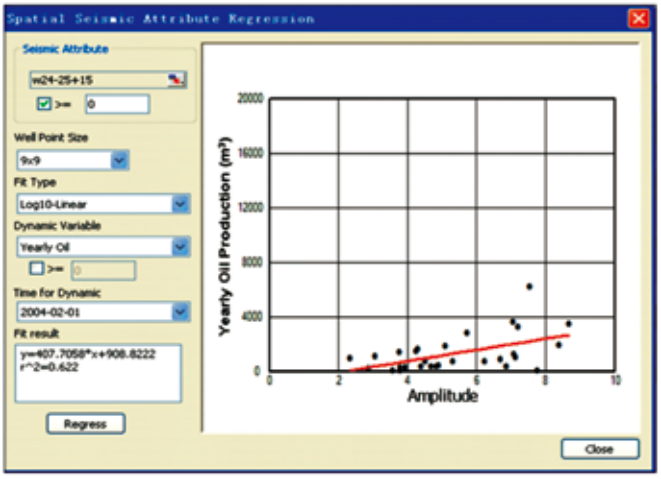
Display chart of comparison of seismic attribute with dynamic data



Seismic-dynamic combined connectedness analysis chart



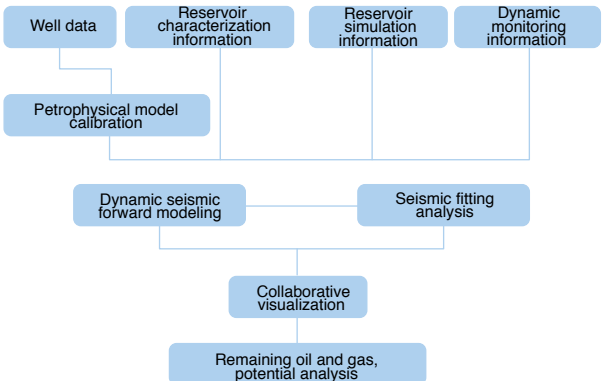
Comparative analysis chart of time-lapse difference attribute and well performance



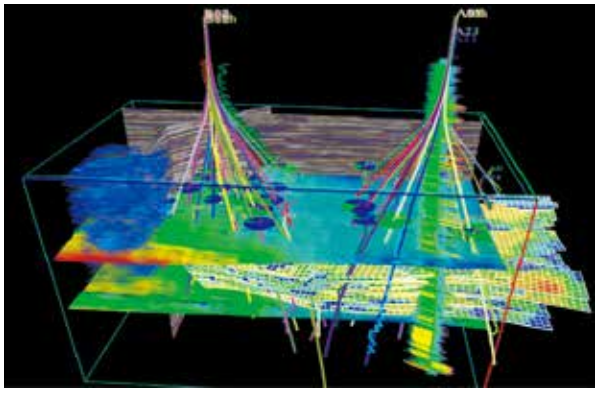
Cross plot of production performance vs. seismic attribute

2.4 Reservoir Integrated Collaboration Subsystem (RI)

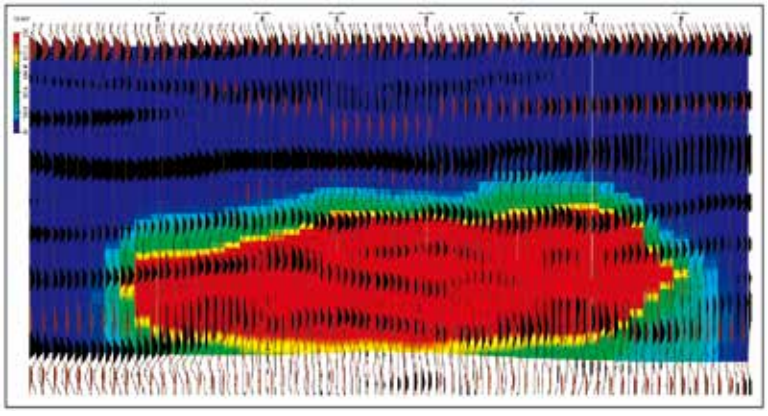
Carry out consistency analysis, statistical analysis and filtration of data through visual analysis of reservoir model, seismic data, well data and well's injection-production performance data. The subsystem has 2D and 3D interactive operation function and can instantaneously synthesize 3D seismic, 4D difference and pre-stack seismic response at any time point. The main functions of the subsystem include: establishing a petrophysical model, realizing the connection of reservoir model with seismic data, multi-domain multidisciplinary data collaborative display and visualization, multi-domain multidisciplinary data collaborative analysis and application, etc.



Technical flow chart of reservoir integrated collaboration subsystem



3D collaborative display chart of multidisciplinary data



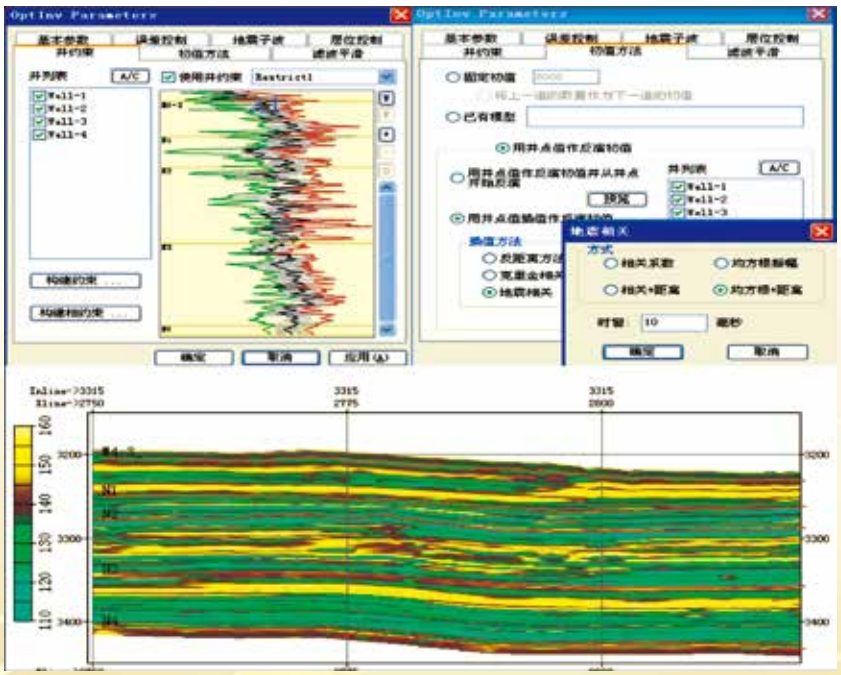
Synthetic seismic and measured seismic comparison profile

3 CHARACTERISTIC TECHNOLOGIES

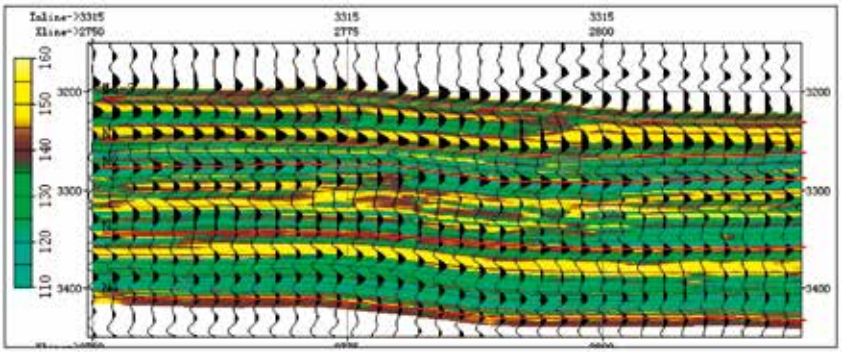
GeoEast-RE has series matching technologies such as statistical inversion technology for seismic data, numerical reservoir simulation technology under seismic dynamic dual constraints, 3.5D seismic analysis technology, connectedness analysis technology under seismic and dynamic constraints, well-seismic-dynamic comprehensive analysis technology, integrated technology of seismic, reservoir simulation, petrophysics and forward modeling, etc. GeoEast-RE is better than domestic and foreign mainstream software in terms of time domain and depth domain switching visualization technology, network domain data interactive management and seismic and dynamic combination technology, etc.

3.1 Statistical Inversion Technology for Seismic Data

GeoEast-RE realizes the inversion method with well statistics special constrains and target function optimization and can greatly increase inversion result resolution capacity, thus establishing a foundation for thin reservoir prediction and fine reservoir characterization.



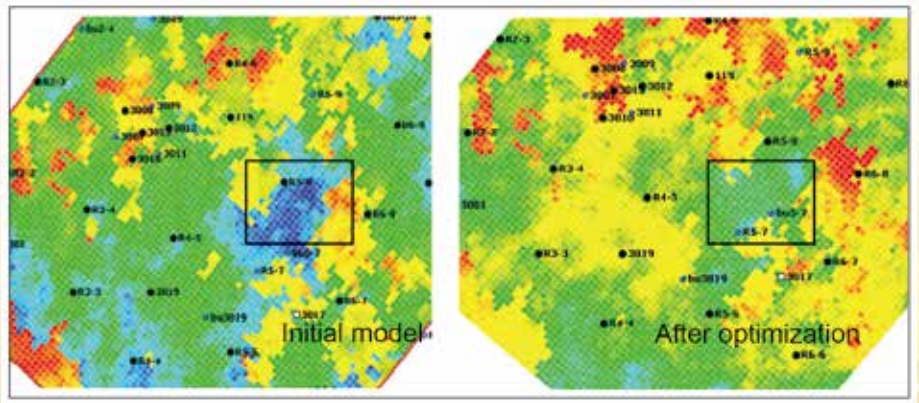
Inversion profile



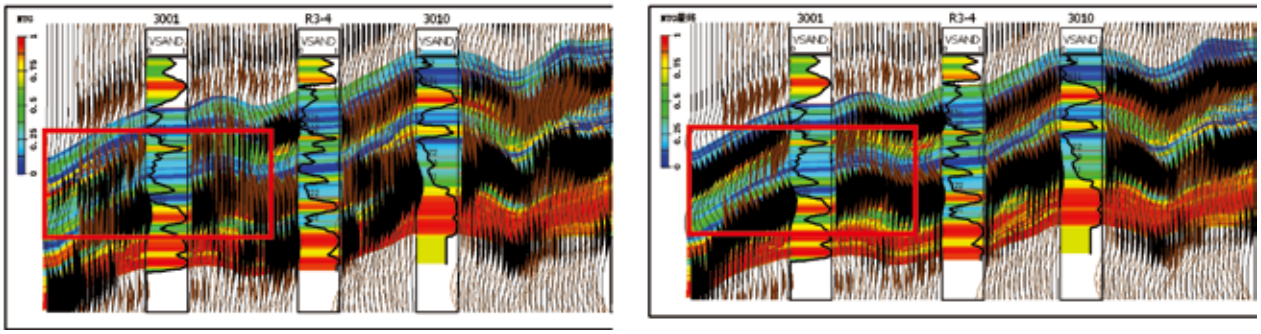
Superposed correlation chart of inversion result vs. original seismic profile

3.2 Numerical Reservoir Simulation Technology under Seismic Dynamic Dual Constraints

Carry out dynamic forward simulation of reservoir model via the calibrated petrophysical model based on the static and dynamic reservoir models, thereby realizing seismic response simulation at any time point. Spatial non-fitting can be quantitatively analyzed through comparison with observation response. The reservoir model is modified interactively in real time combining dynamic non-fitting in wells, thus realizing history matching of seismic constraints, expanding the process flow of reservoir model updating only with traditional dynamic non-fitting in wells and providing a new approach for improving reservoir model reliability.



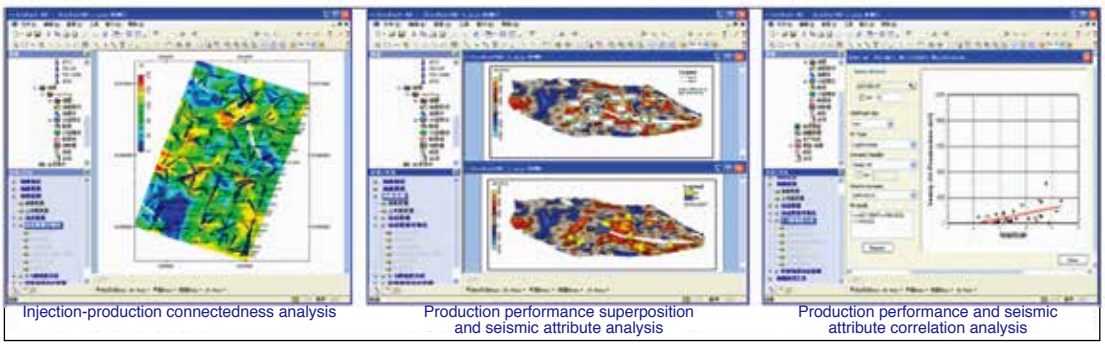
Reservoir simulation porosity field correlation chart modified according to seismic correlation difference



Comparison chart of synthetic seismic vs. measured seismic before and after reservoir model modification

3.3 3.5D Seismic Analysis Technology

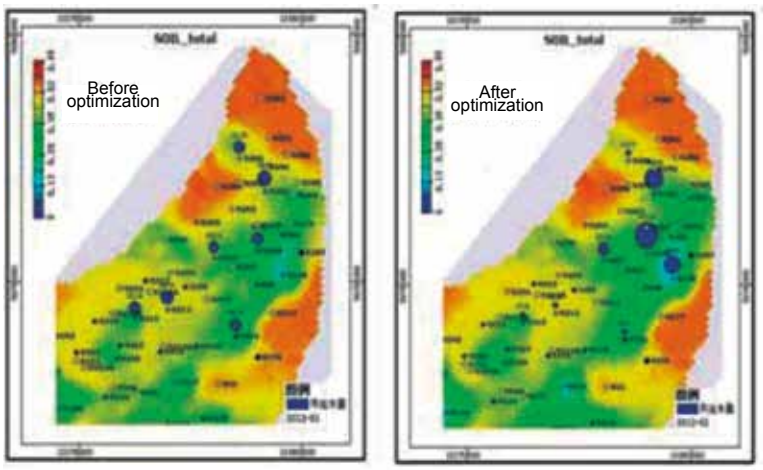
Combine decline analysis and reserves analysis with seismic attribute analysis through dynamic data domain seismic attribute stacking; identify potentials through seismic attribute and production data correlation analysis and filtering or correction of seismic attribute data with production data. There are dynamic characteristic data and seismic attribute, relevant well information analysis methods and simplified mutual conversion tools, thus providing geologic factors and analysis approaches for the comprehensive analysis of combination of seismic data with spatial distribution of dynamic data.



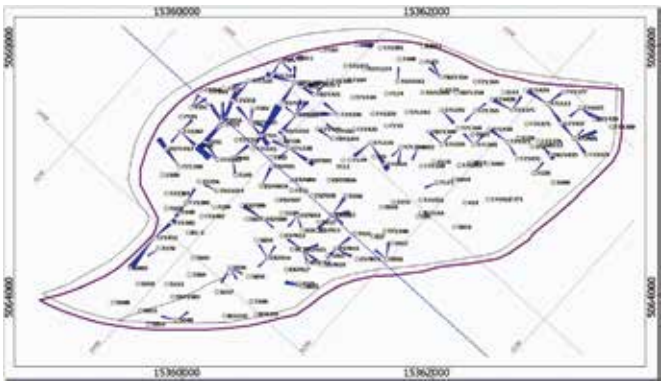
3.5D seismic analysis chart

3.4 Connectedness Analysis Technology under Seismic and Dynamic Constraints

GeoEast-RE can be used to calculate inter-well connectedness meeting the requirements of dynamic history and spatial attribute relation characteristics with the seismic attribute spatial relation as constraints based on dynamic history and material balance theory, thus providing quantitative analysis tools for inter-well connectedness analysis.



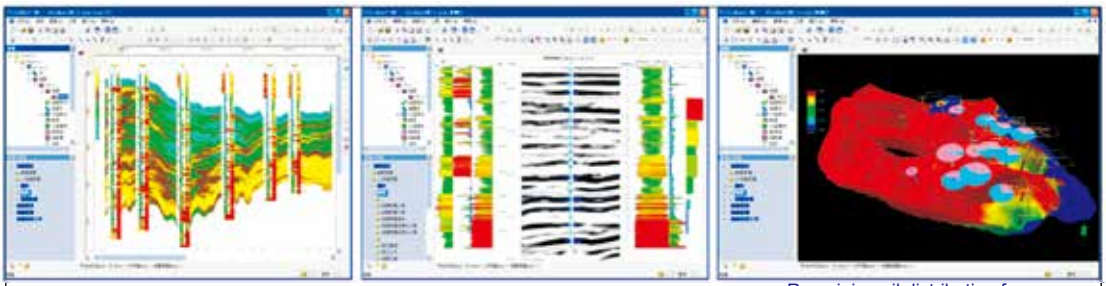
Comparison chart of optimization area injection with original injection



Comparison chart of whole-area connectedness analysis result

3.5 Well-Seismic-Dynamic Comprehensive Analysis Technology

The technology becomes the well-seismic-dynamic comprehensive analysis tool through convenient visualization of multi-dimensional well-seismic information and multiple sorts of well information as well as dynamic information analysis, thereby overcoming the disadvantages of failure to carry out visual analysis with dynamic information through traditional well-seismic analysis. Dynamic significance is given to well-seismic space analysis in the development stage. Qualitatively analyze and verify the connectedness of sand bodies and further recognize seismic response characteristics.

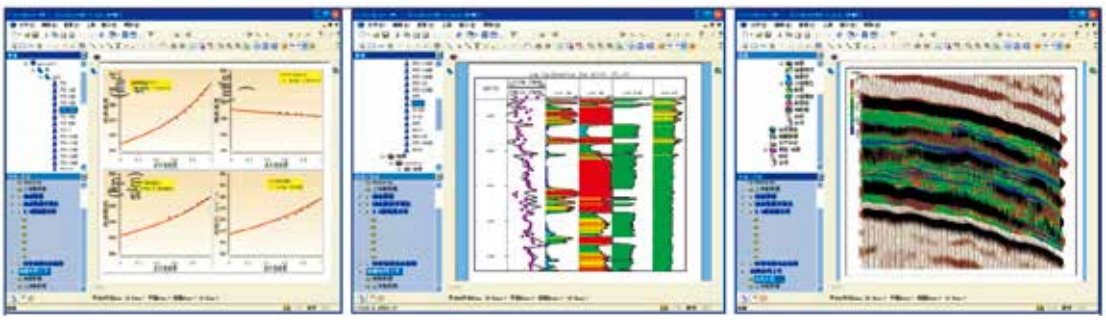


Well-seismic joint inversion | Well-seismic calibration | Remaining oil distribution from production history superposition

Well-seismic-dynamic comprehensive analysis chart

3.6 Integrated Technology of Seismic, Reservoir Simulation, Petrophysics and Forward Modeling

Visualize the binding and collaboration of seismic with reservoir model through logging comparative analysis of petrophysical simulation calibration and petrophysical model; determine the fitting difference through history matching constraint with seismic data (3D seismic, time-lapse seismic, pre-stack, multi-wave seismic data, etc.); carry out collaborative visualization and quantitative analysis of the error between reservoir model synthesis attribute and observation attribute and achieve the purpose of interactively updating the reservoir model, thereby realizing integrated seismic, reservoir simulation, petrophysics and forward modeling.



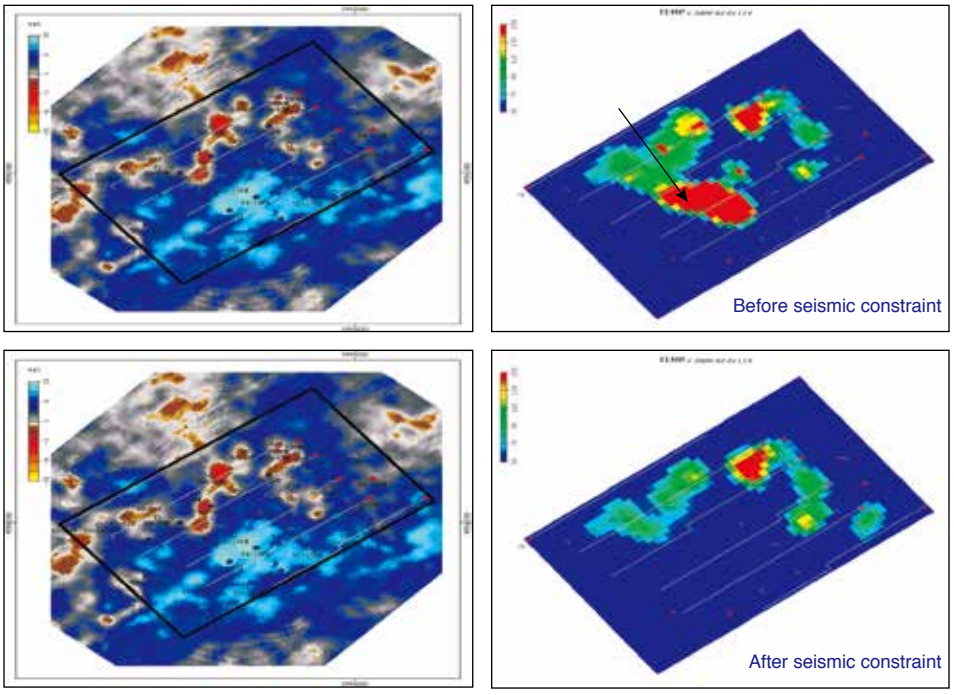
Petrophysical model calibration | Petrophysical model analysis | Forward modeling correlation

Analysis chart of integrated seismic, reservoir simulation, petrophysics and forward modeling

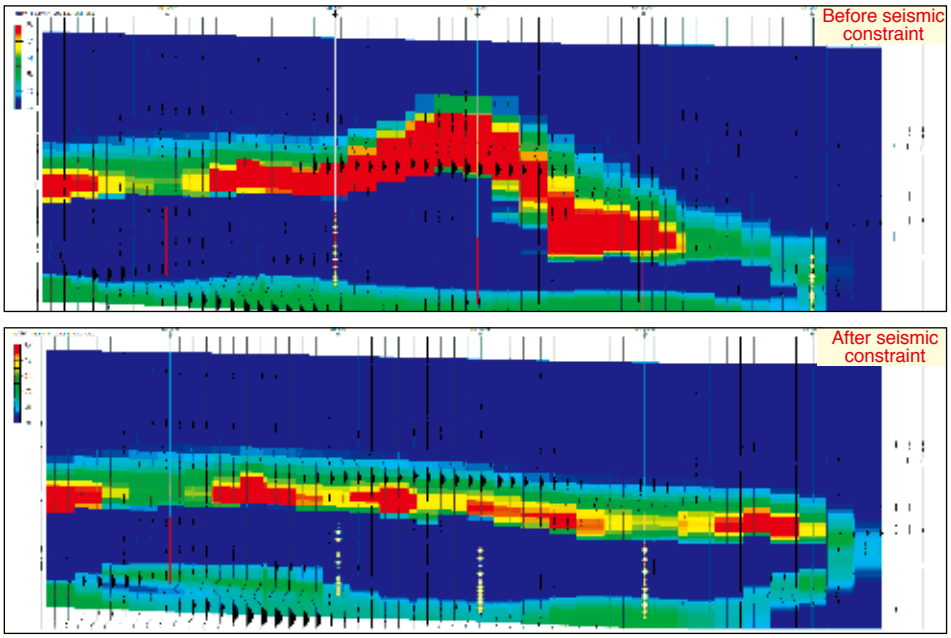
4 TYPICAL CASES

4.1 SAGD of Thick Oil in Liaohe Basin

Liaohe Shuguang SAGD development area is PetroChina's main region of thick oil development; however, the pattern distribution after steam injection cannot be determined accurately, thus making development adjustment difficult. Therefore, PetroChina has carried out SAGD 4D seismic field tests. Based on the acquired 4D seismic data, the reservoir model is quantitatively controlled and checked using the petrophysical model and integrated technology involving seismic forward modeling etc. in GeoEast-RE. The reservoir model has been continuously updated with the seismic constrained history matching technology, thus obtaining a good history matching result. With the multi-data collaborative visualization technology, steam chambers have been interpreted and a reperforating scheme has been proposed.



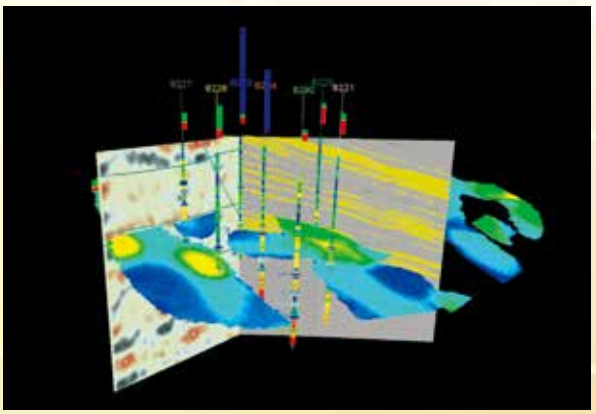
Temperature field comparison chart before and after seismic constraint



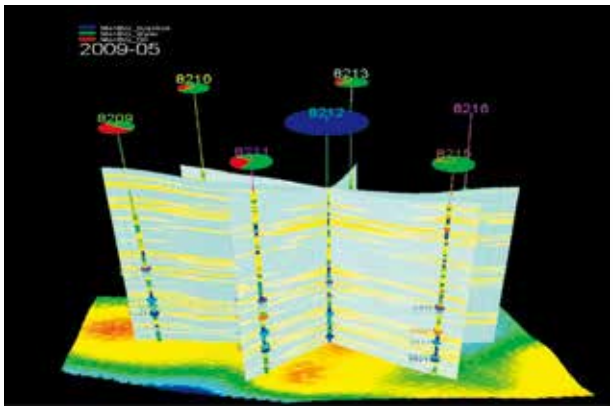
Comparison chart of seismic difference with temperature difference before and after model modification

4.2 Water Drive Reservoir Development Example in Junggar Basin

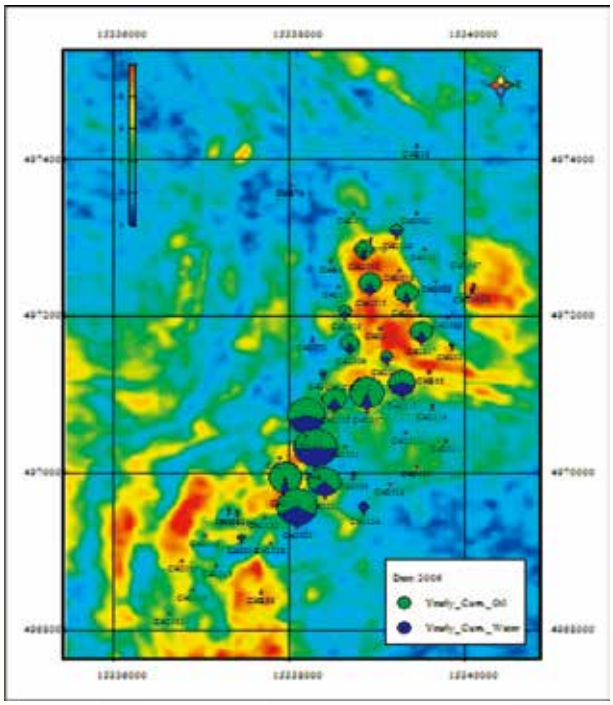
PetroChina has carried out seismic applications in the secondary development of Junggar region; i.e. seismic applications in development are realized through secondary seismic data acquisition in the developed old oilfield taking development and EOR as the objective. The spatial potential of Che-76 oilfield has been analyzed using the dynamic-seismic attribute integrated analysis method in GeoEast-RE technology. Inter-well connectedness has been quantitatively calculated and the water injection scheme has been optimized with time-lapse seismic constraints in Cainan oilfield. Reperforating and sand body connectedness have been analyzed in Xibuyuan oilfield using the multi-data collaborative visualization technology and a good effect has been obtained, thereby systematically carrying out seismic application in secondary development and forming the technical flow under different data conditions.



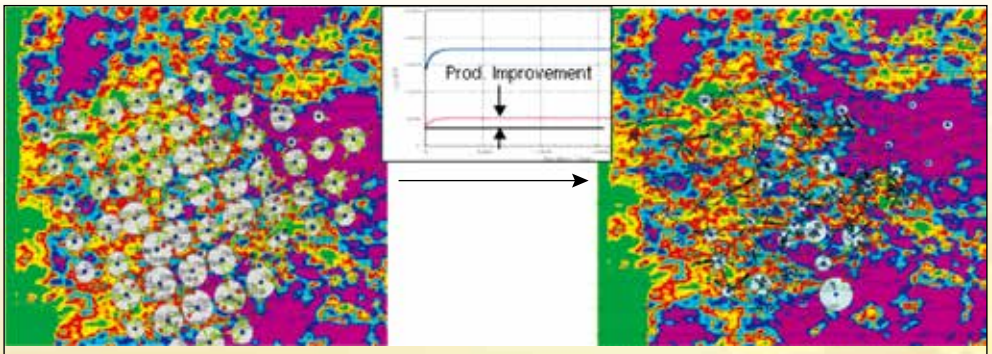
Distribution chart of logging, seismic, static simulation, production data and single sand bodies



Analysis chart of connectedness and dynamic data of injection wells and production wells based on the sand body model



Injection-production scheme optimization with 4D seismic constraints



Injection pattem before optimization

Injection pattem after optimization (no cost increase)

Seismic attribute and dynamic combined analysis chart

5 SCIENTIFIC RESEARCH EQUIPMENT

Research & Development Center, BGP Inc., CNPC has a high performance parallel cluster, which has totally 20790 CPUs with 76458 cores and 824 GPUs with 470000 cores, with the FLOPS of 1497Tflops and the total storage capacity of 20000TB.

6 QUALIFICATION STANDARDS

Research & Development Center, BGP Inc., CNPC is a comprehensive geophysical technology research institution integrating seismic data acquisition, processing and interpretation method research and software development and the national engineering research center for oil and gas exploration computer software and has passed quality management system certification and CMMI grade III certification. Headquartered in Zhuozhou, Hebei, the Research & Development Center has two branch centers such as Beijing (Changping) Branch Center and Houston Research Branch Center and widely cooperates with international and domestic well-known research institutions to continuously promote geophysical technology advance.

Passed the state acceptance inspection on Oct. 31, 2000

CMMI level III certification

Quality management system certification

Intellectual property rights

The Research & Development Center has applied for 6 national invention patents and has 5 registered software copyrights.

No.	Name of intellectual property rights	Type of intellectual property rights	Application No./ authorization No.
1	A method for automatic conversion of time-depth relation between seismic and logging	China invention patent	201210250721.9
2	A separation and waveform reconstruction method for waveform extreme characteristic points of seismic data and logging data	China invention patent	201210366105.X
3	A method for determining sedimentary features and distribution of reservoirs jointly with well-seismic information	China invention patent	201210584609.9
4	A method for determining the form of SAGD steam chamber	China invention patent	201210286322.8
5	A method for identifying interbeds using well temperature data	China invention patent	201210405098.X
6	A reservoir model optimization method for AVO gather analysis	China invention patent	201410142188.3
7	GeoEastRE-RI reservoir geophysical system analysis software V1.0	Software copyright	2013SR062650
8	GeoEastRE-RD reservoir description software V1.0	Software copyright	2013SR062567
9	GeoEastRE-RM reservoir monitoring data analysis software V1.0	Software copyright	2013SR061468
10	GeoEastRE-RS numerical reservoir simulation integrated analysis software V1.0	Software copyright	2013SR062654
11	GeoEastRE-RE reservoir geophysical software V1.0	Software copyright	2013SR061462

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