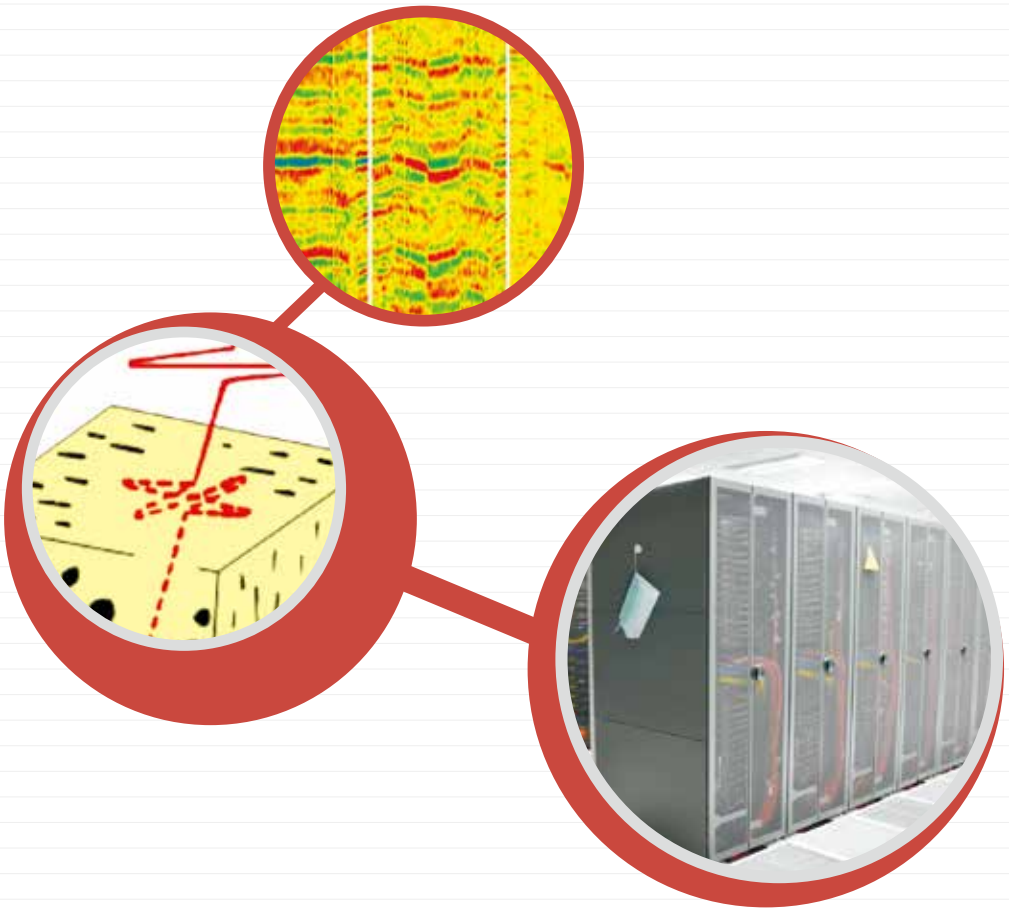
GeoEast-MC Multi-component Seismic Data Processing System

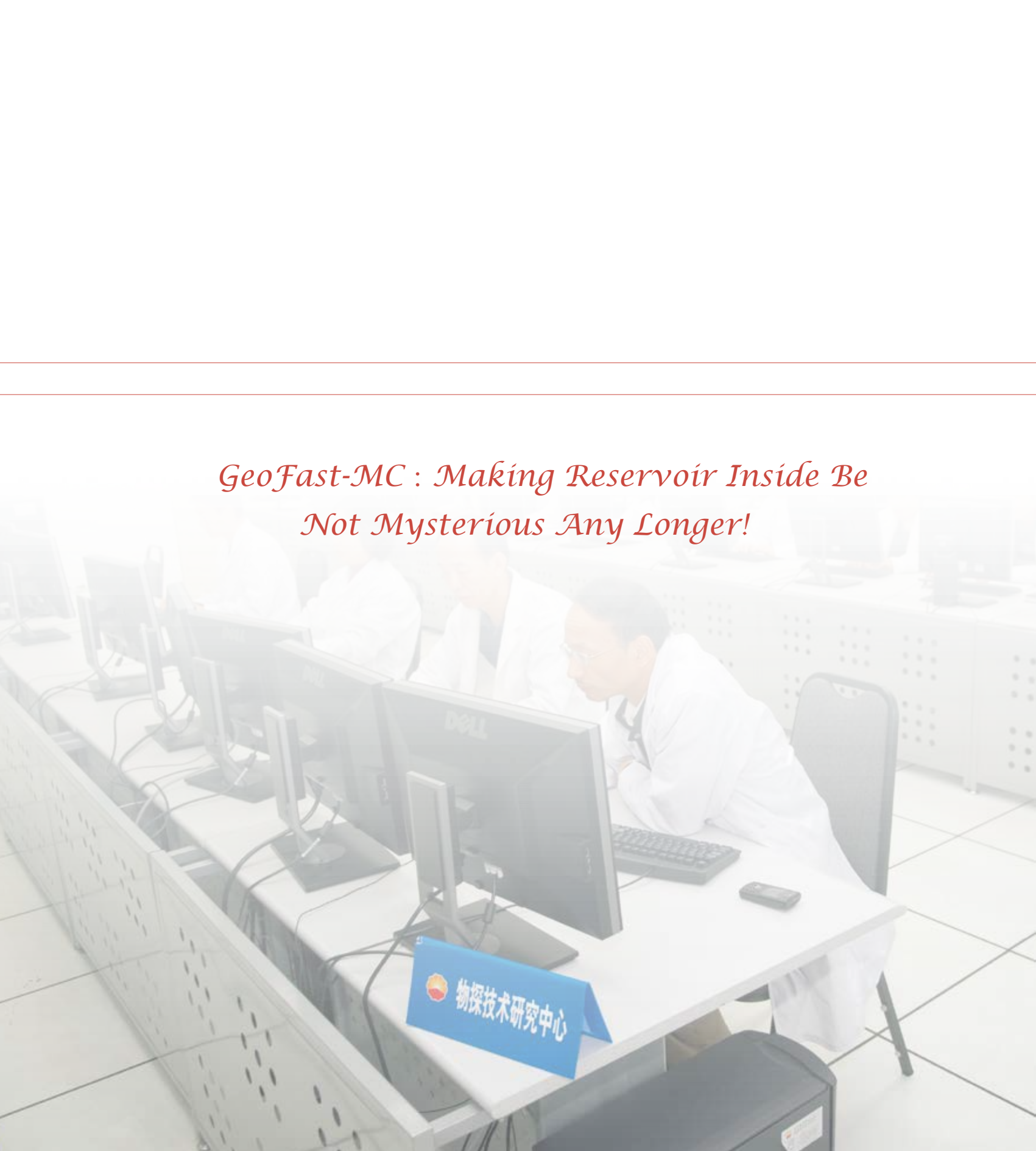
Science & Technology Management Department, CNPC

2015



CHINA NATIONAL PETROLEUM CORPORATION

GeoFast-MC : Making Reservoir Inside Be Not Mysterious Any Longer!



Contents

1 Introduction 3

2 Module Functions 4

3 Characteristic Technologies 6

4 Typical Cases 14

5 Scientific Research Equipment 16

6 Qualification Standards 17

7 Expert Team 18

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.

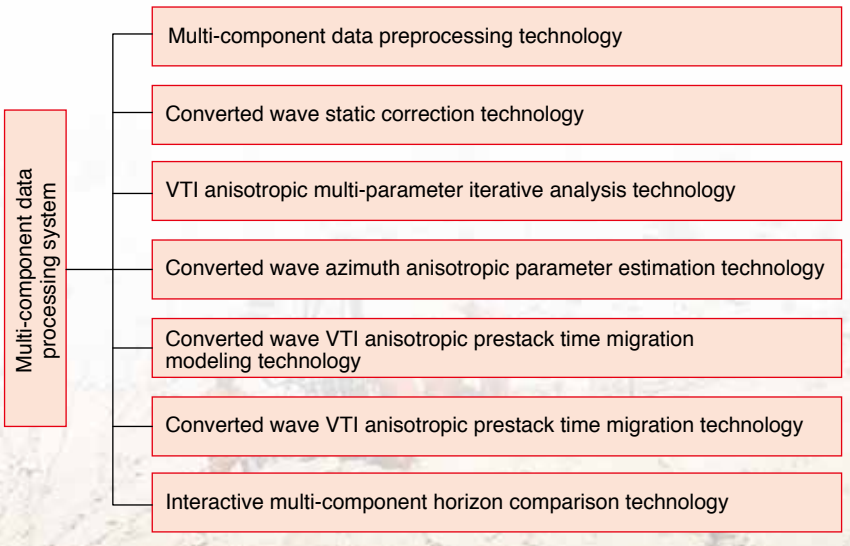
CNPC strictly follows by the combined strategies of increasing resource capacity, expanding market shares and consolidating the international role, and persists in regarding technical innovation as a key framework to advance technological progress. To develop its core businesses, focuses will be placed 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-MC multi-component seismic data processing system is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

1 INTRODUCTION

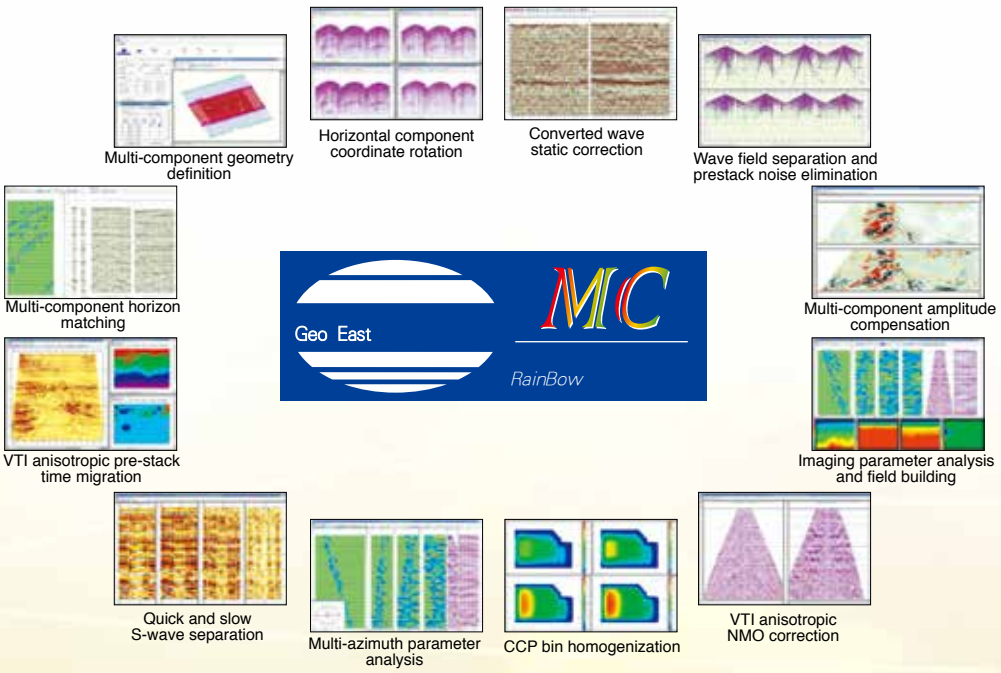
Multi-component seismic exploration can improve structure and reservoir imaging, identify lithology and fluid, detect fractures and directly predict oil and gas. In recent years, multi-component seismic exploration has become important means for exploration of complex reservoirs and unconventional reservoirs. GeoEast-MC multi-component seismic data processing system developed by CNPC has inherited the advantages of GeoEast integrated system such as multi-information coexistence, visual interaction, integrated collaborative processing and interpretation, etc. The software is characterized by friendly interface, simple operation and stable running and its integral technology has reached the international advanced level. The system takes the lead internationally in converted wave static correction, imaging parameter estimation and field building, converted wave azimuth anisotropic processing and VTI anisotropic pre-stack time migration, is the first set of domestic multi-component data processing software system with large-scale actual production capacity, and has filled up the gap of domestic multi-component data processing software.



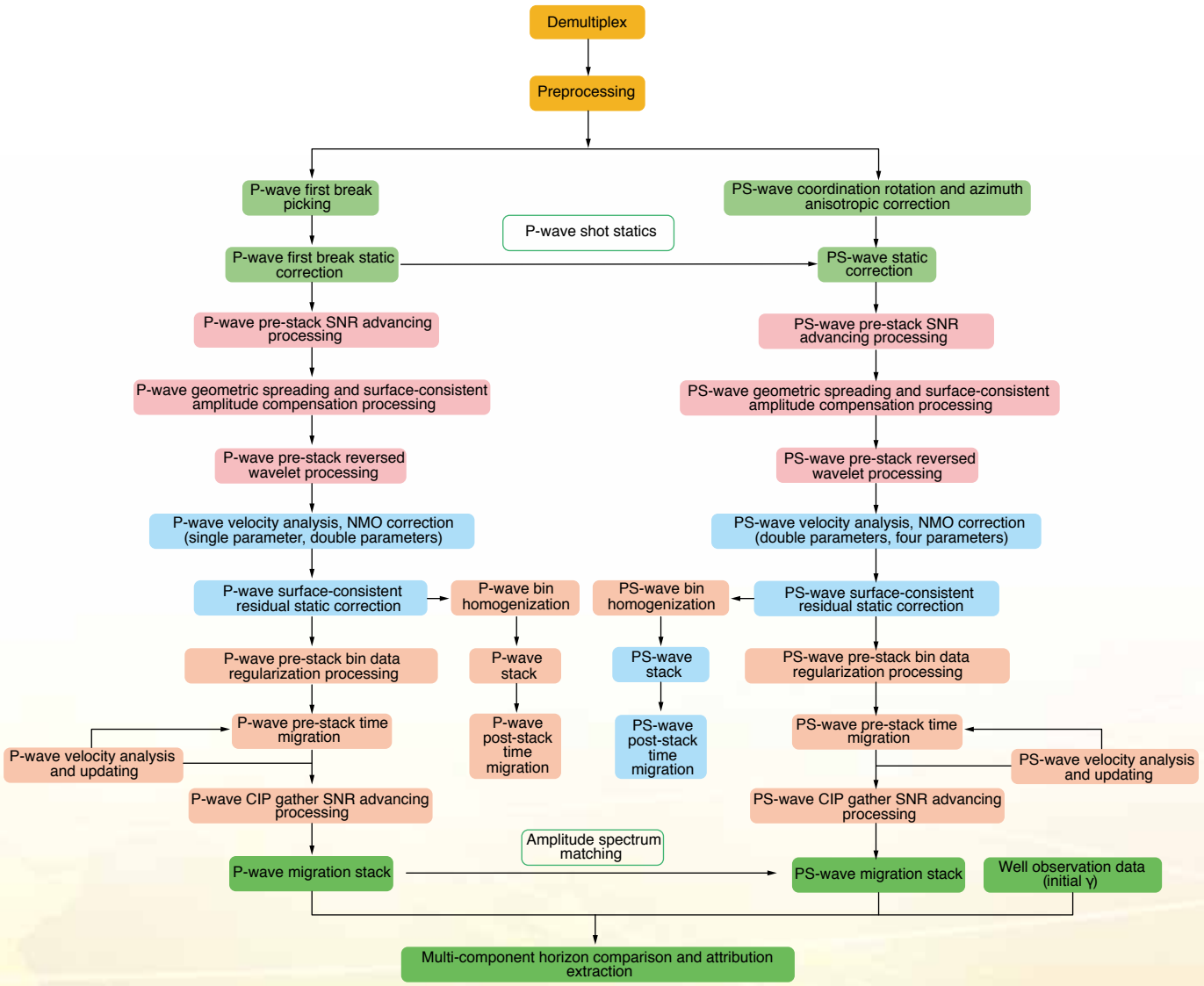
GeoEast-MC technology framework

2 MODULE FUNCTIONS

GeoEast-MC multi-component seismic data processing system has 25 function modules and can independently complete the technical process of 2D/3D marine and onshore multi-component seismic data time imaging.



Main Functions of GeoEast-MC System



Technology process of GeoEast-MC System

3 CHARACTERISTIC TECHNOLOGIES

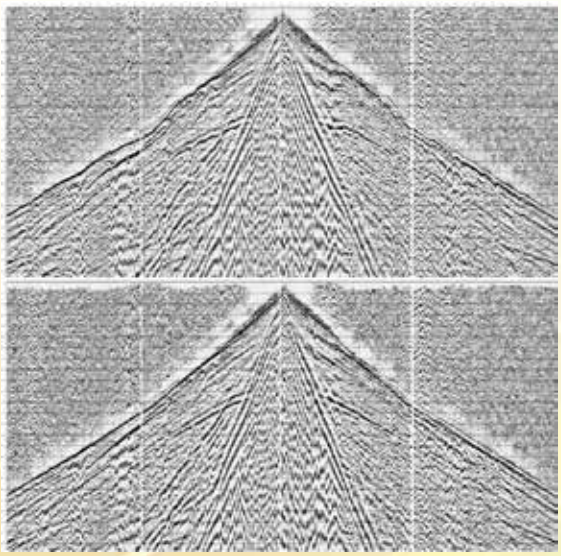
GeoEast-MC multi-component seismic data processing system has proprietary intellectual property rights, integrates multiple characteristic technologies such as converted wave static correction, multi-component imaging parameter estimation and field building, converted wave azimuth anisotropic correction, converted wave pre-stack time migration, etc., and can meet the need of large-scale multi-component data processing.

3.1 Converted Wave Static Correction Technology

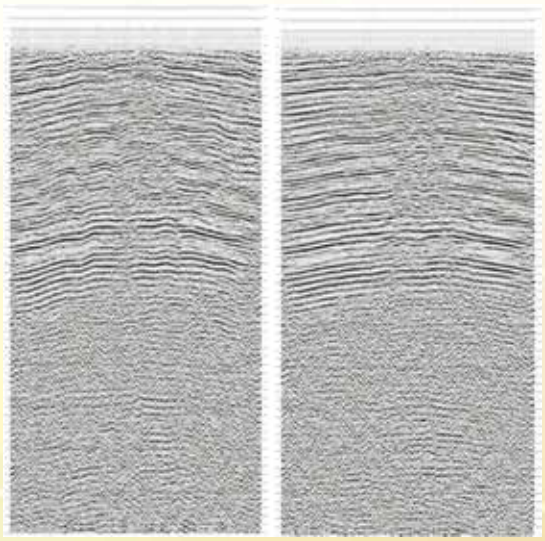
The technology includes two methods including first break time difference method and P-wave structure constraint method. In combination with the conventional static correction processing technology in GeoEast system, the converted wave static correction technology has the capacity of solving actual 2D/3D converted wave seismic data static correction problems and can effectively improve the imaging quality of converted waves.

◆ Converted wave static correction with the first break time difference method

The method that can be used to calculate the statics of both long wavelength component and short wavelength component of converted waves, is an effective S-wave static correction method, and especially applies to the calculation of converted wave statics in low SNR regions.



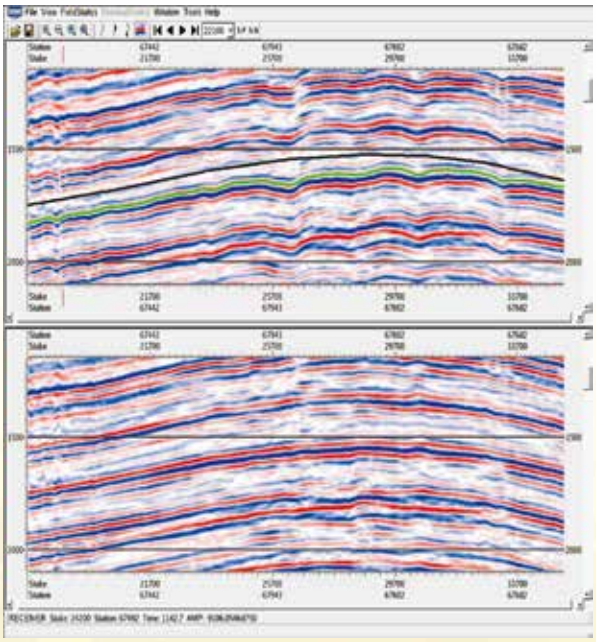
Single short before (upper) and after (lower) converted wave static correction with the first break time difference method



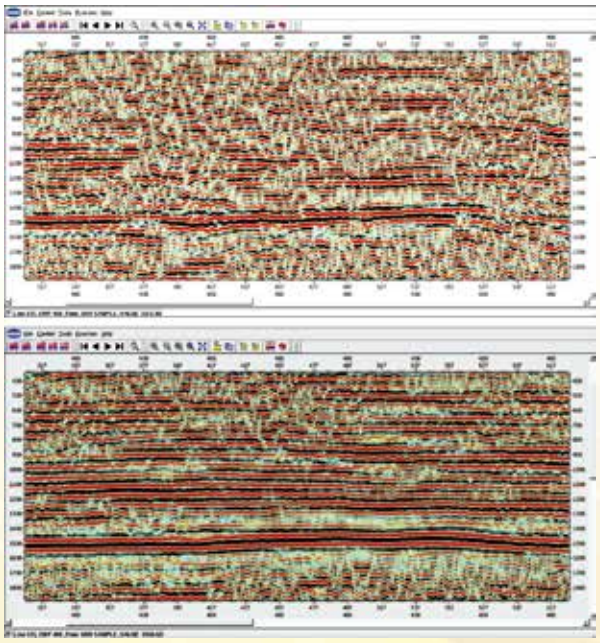
Stack before (left) and after (right) converted wave static correction with the first break time difference method

◆ Converted wave static correction with the P-wave structure constraint method

The method can be used to calculate large S-wave statics of converted wave geophones. Through horizon matching on the profile of P-wave and converted wave, S-wave statics is obtained. The method is simple and stable, can effectively calculate large S-wave statics of converted wave geophones and has high adaptability.



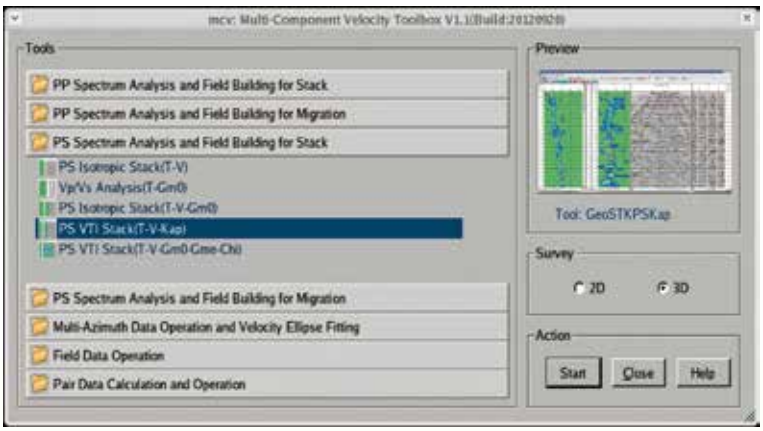
Common receiver point stack profile before (upper) and after (lower) converted wave static correction with the P-wave structure constraint method



CCP stack profile before (upper) and after (lower) converted wave static correction with the P-wave structure constraint method

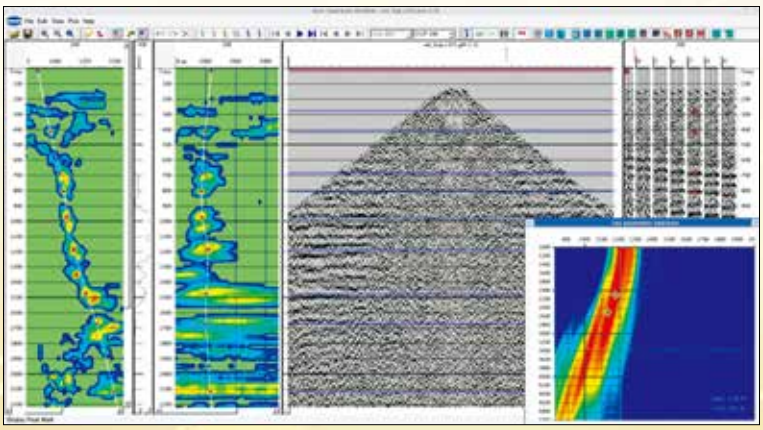
3.2 VTI Anisotropic Multi-Parameter Iterative Analysis Technology

GeoEast-MC multi-component processing system has plentiful parameter estimation functions, consists of over 40 relatively independent mutual tools, integrates the currently advanced multi-component time domain imaging parameter estimation algorithms, has very high adaptability, and can meet different actual production needs.



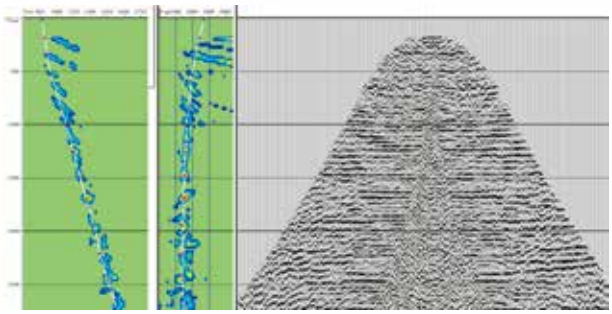
Multi-component imaging parameter estimation and field building

◆ Converted wave isotropic dual-parameter analysis



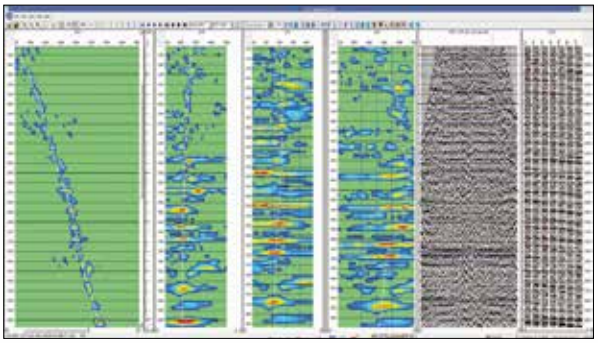
Converted wave velocity V_0 | Vertical velocity γ_0 | NMO correction gather | Dual-parameter spectrum

◆ Converted wave anisotropic dual-parameter analysis



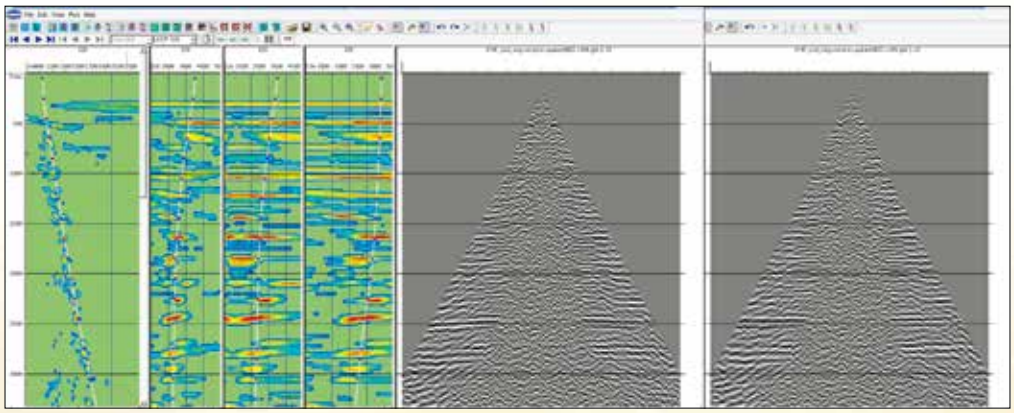
Converted wave velocity V_c | Equivalent Anisotropic parameter K_{eff} | NMO correction gather

◆ Converted wave anisotropic four-parameter analysis

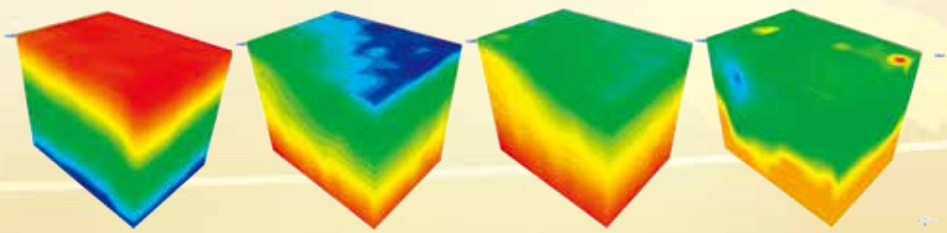


V_c γ_0 γ_{eff} χ_{eff}

◆ Converted wave anisotropic prestack time migration parameter updating and field building



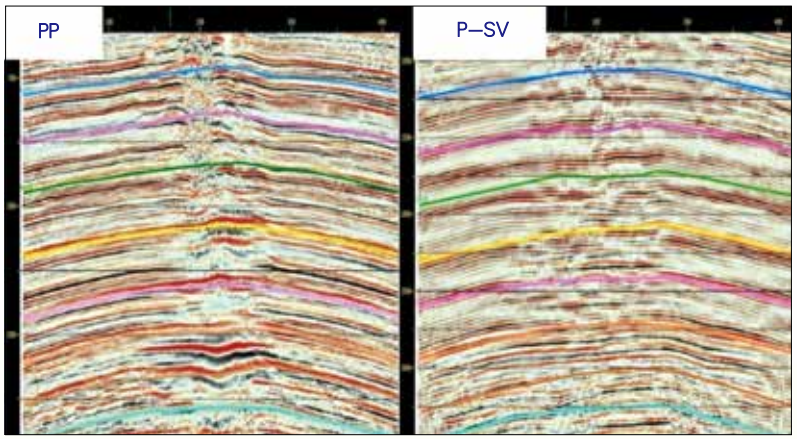
V_c γ_0 γ_{eff} χ_{eff} Gather before updating Gather after updating



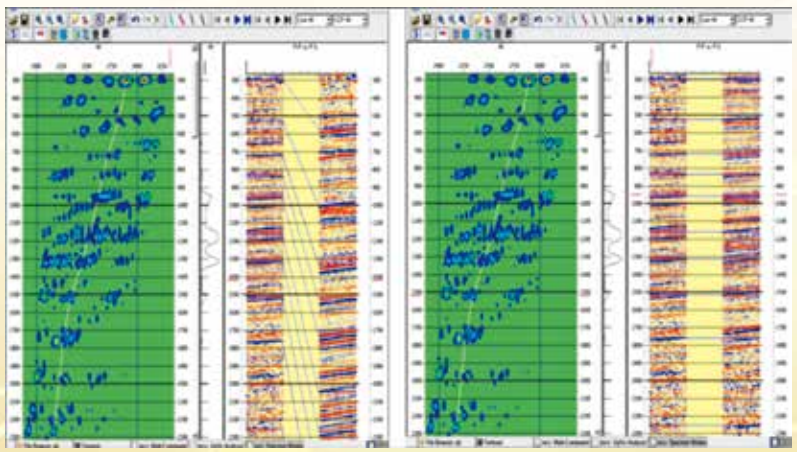
Converted wave velocity V_c | Vertical velocity γ_0 | Equivalen velocity ratio γ_{efft} | Anisotropic parameter χ_{efft}

◆ Vertical velocity ratio analysis

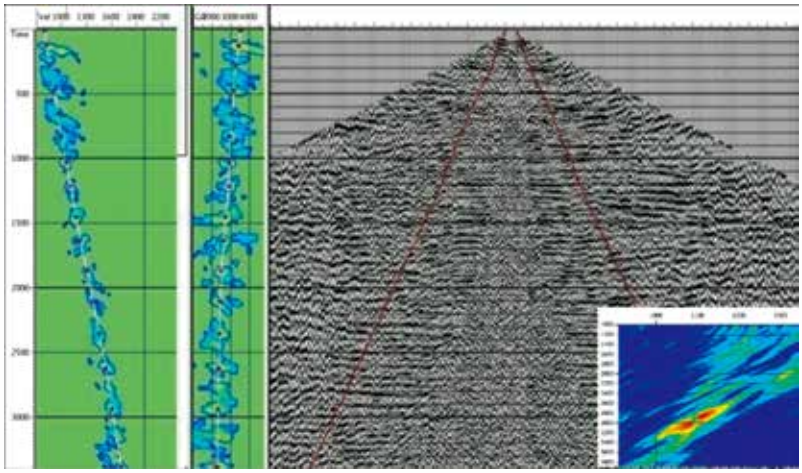
Provide multiple vertical velocity ration analysis methods based on pre-stack and post-stack data and thus reliable velocity ratio parameters for improving converted wave imaging quality and subsequent multi-component data interpretation.



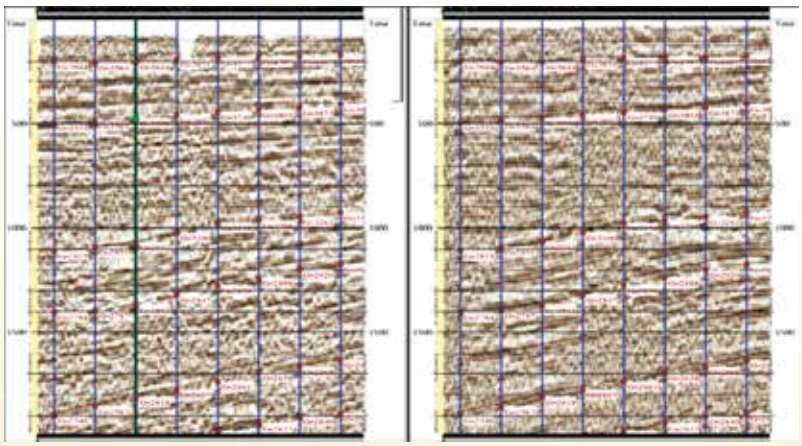
Interactive pickup horizon of P-wave and converted wave profile



Corresponding CDP/CCP sweep



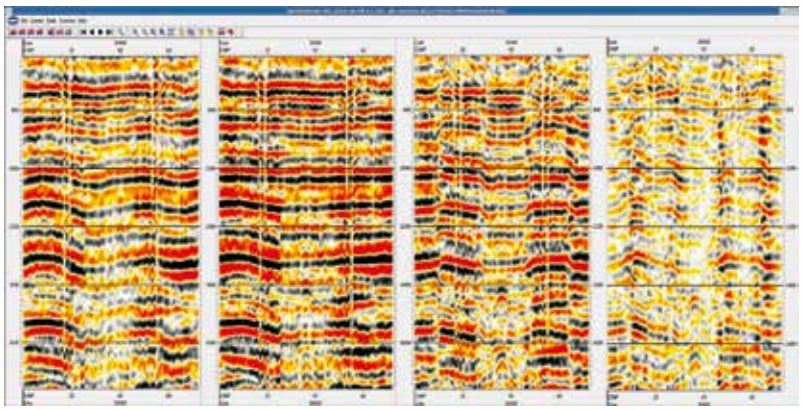
Pre-stack dual-parameter sweep



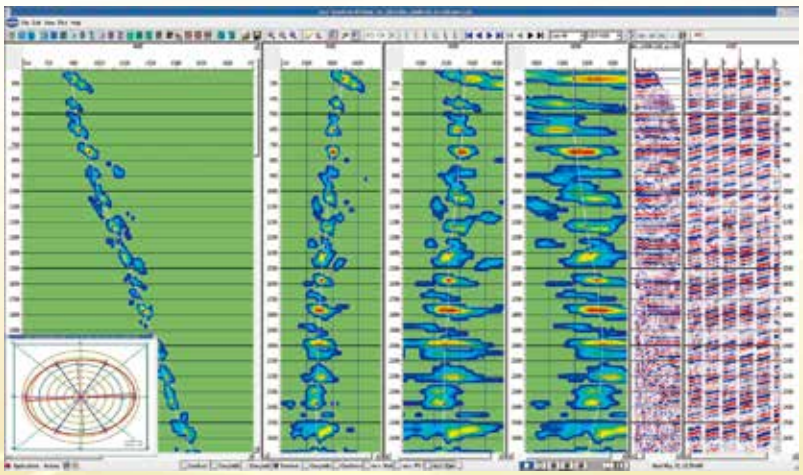
Post-stack corresponding point pickup

3.3 Converted Wave Azimuth Anisotropic Parameter Estimation Technology

Realize azimuth anisotropic parameter estimation through grouped processing of common conversion point data as per azimuth; support multi-azimuth velocity spectrum interactive interpretation, field data ellipse fitting, smoothing, operation, etc.



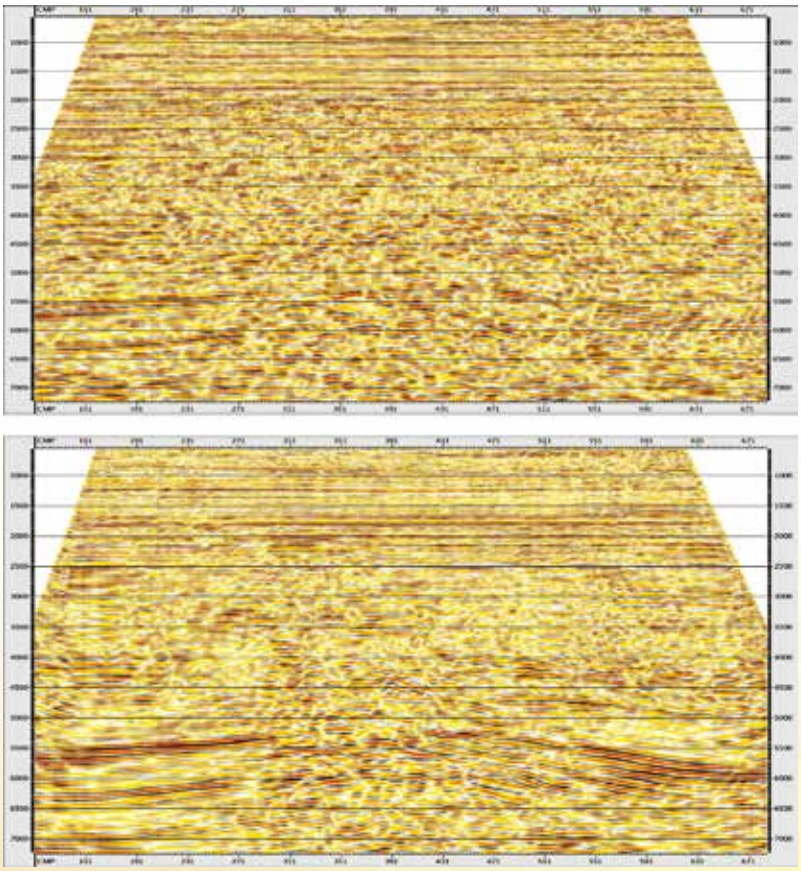
R component and *T* component before and after S-wave splitting analysis and compensation



Converted wave azimuth anisotropic imaging parameter estimation

3.4 Converted Wave VTI Anisotropic Pres-tack Time Migration Technology

Have the functions including isotropic direct rays/bending rays and VTI anisotropic direct rays/bending rays, etc.; improve imaging precision via amplitude weighting suitable for converted waves and de-alias filtering technology; practically improve time migration efficiency using multiple parallel calculation measures such as MPI parallelism, instruction parallelism, etc., which can thus meet the processing need of large-scale multi-component seismic data time domain imaging.



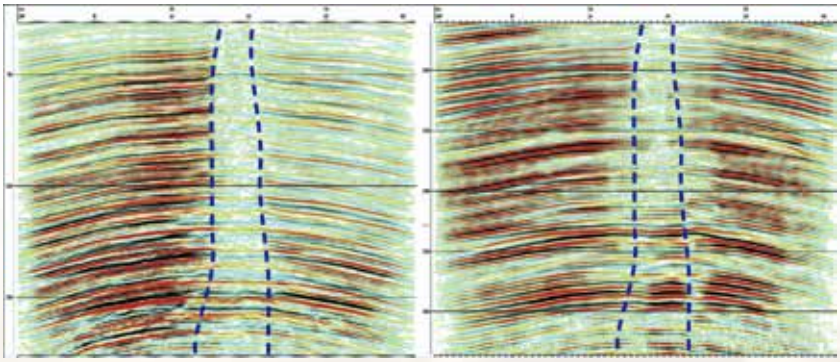
Converted wave post-stack time migration (upper) and anisotropic pre-stack time migration (lower) imaging

4 TYPICAL CASES

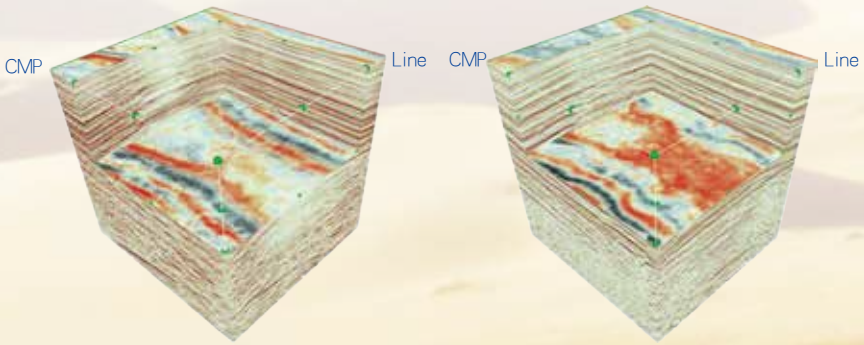
GeoEast-MC system has completed the processing of over 10 3D multi-component data of Venezuela, Qinghai Sanhu, Tarim Lungu, Changqing Sulige, Saudi Arabia, Jinzhou, etc., and very good application effects have been obtained.

4.1 Qinghai Sanhu Gas Chimney Imaging

The near-surface structure of Qinghai Sanhu region is complex, and surface velocity anomaly and gas bearing anomaly are mutually superposed, so that the SNR of data is low and the static correction problem is serious. With GeoEast-MC system, high quality converted wave imaging data have been obtained, the form features of the nose-like bulge between Tainan structure and Sebei 1# structure have been finely depicted, the boundaries of the gas cloud area have also been clearly depicted, and small amplitude structures have been further ascertained.



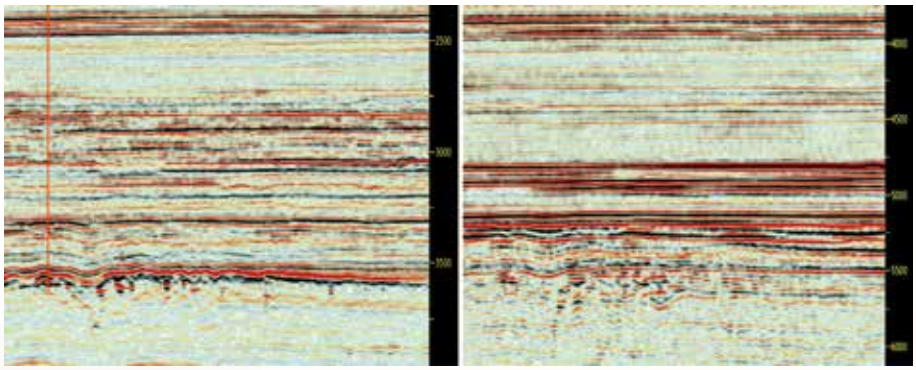
Anisotropic pre- stack time migration profile of P-wave (left) and converted wave (right) in Qinghai Sanhu



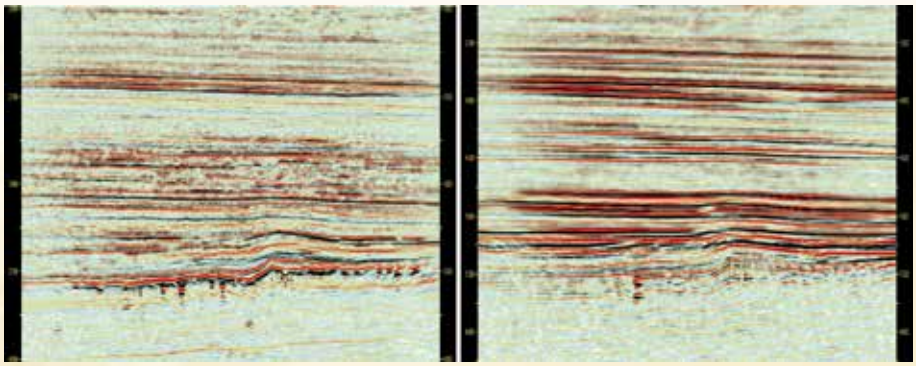
Anisotropic pre-stack time migration data volume of P-wave (left) and converted wave (right) in Qinghai Sanhu

4.2 Subsalt Imaging in Lungu-17 Well Area in Tarim Basin

Tarim Lungu-17 well area has dense vegetation, well sites, oil transmission pipelines and highways, so that receiving conditions are not good and it is difficult to ascertain structures. With GeoEast-MC software, converted wave data volumes with obviously better SNR and resolution than P-wave have been finally obtained and the features of deep Ordovician carbonate inner buried hills have been clearly indicated, thereby providing reliable result data for further ascertaining Carboniferous and Triassic low amplitude structures and traps.



Anisotropic pre-stack time migration of P-wave (left) and converted wave (right) in Lungu-17 well area in Tarim basin



Anisotropic pre-stack time migration of P-wave (left) and converted wave (right) in Lungu-17 well area in Tarim basin

5 SCIENTIFIC RESEARCH EQUIPMENT

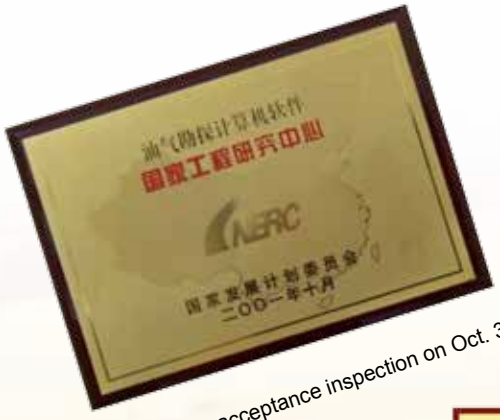
Research & Development Center, BGP Inc., CNPC has a high performance parallel cluster, which has totally 20790 CPUs with 76458 cores and 824 GPUs with 470000 cores, with the FLOPS of 1497Tflops and the total storage capacity of 20000TB.

High performance parallel computer cluster

Large terminal equipment room

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

7 EXPERT TEAM

Qian Zhongping

Professor level sensor engineer, doctor. He has long been engaged in geophysical exploration technology research and development work and undertakes the R&D of the multi-component seismic data high-precision imaging processing matching technology in the national “twelfth five-year” major special research subject “multi-component seismic exploration and fractured reservoir prediction matching technology”. He has obtained 1 patent, and over 20 papers written by him have been published.

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Li Xiangyang

Professor, Ph. D. candidate supervisor. He is the director of the International Department of CNPC Geophysical Exploration Key Laboratory. He is the leader of national “twelfth five-year” major special subjects and one of the first batch of introduced “thousand-person plan” talents. He was once awarded with China science and technology cooperation prize in 2007. He has been long engaged in seismic anisotropic theory research and multi-component seismic exploration technology R&D and has obtained 2 national invention patents, and multiple international papers written by him have been published.

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Hou Aiyuan Professor senior engineer. He is engaged mainly in the study of exploration and seismic data processing methods and software development and takes charge of studying and developing the VSP processing software package for domestic GeoEast seismic data processing system. He has obtained 5 patents, and 3 papers written by him have been published.
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Sun Pengyuan Senior engineer, doctor. He is engaged mainly in multi-wave multi-component seismic exploration technology research and R&D of geophysical exploration software. He is responsible for R&D of multi-component seismic data processing function in GeoEast seismic data processing system. He has obtained 9 patents, and over 30 papers written by him have been published.
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Li Jianfeng Senior engineer. He is engaged mainly in seismic data processing method research and software development. He has obtained 1 patent, and 6 papers written by him have been published.
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Cheng Chunhua

Engineer. She is engaged mainly in seismic data processing technology research. She is responsible for data processing projects many years. She is specialized in special processing and multi-component data processing. She has 1 paper published.

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Yang Jun

Engineer. He has nearly 20 years of seismic data processing experience. He is engaged in seismic data processing research many years.

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Liu Zengqiang

Senior engineer. He is engaged mainly in seismic data processing and interpretation method research and software R&D and takes charge of conventional velocity analysis and field building in GeoEast integrated seismic data processing and interpretation system as well as R&D of time-depth conversion and multi-component multi-parameter analysis and field building.

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Chen Haifeng

Engineer. He is engaged mainly in multi-component exploration technology research. He is responsible for developing multi-component processing software system. He is specialized in converted wave static correction, anisotropic time domain parameter estimation and imaging technology, etc. He has obtained 5 patents, and 6 papers written by him have been published.
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Yue Yuanyuan

Engineer. She is competent in multi-component processing method research and software development. She is responsible for studying multiple key converted wave processing technologies and developing 7 multi-component processing modules.
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