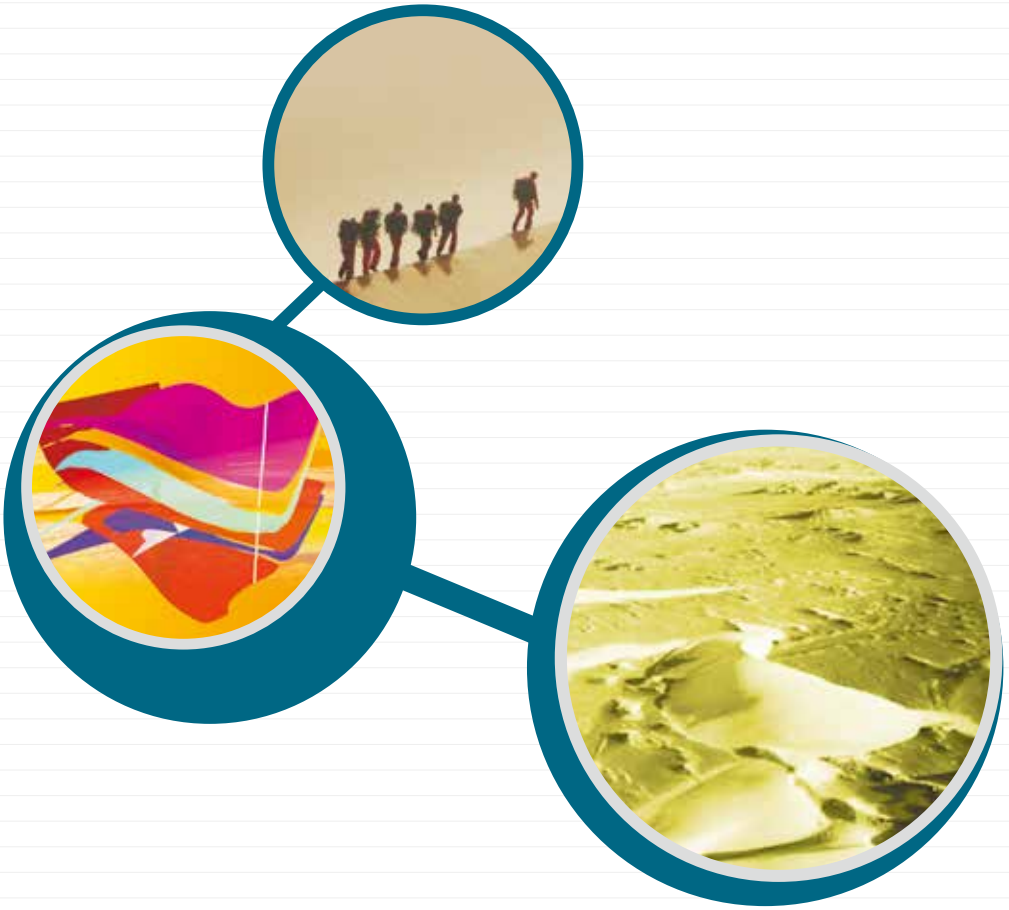
GeoEast-Tomo 3D Prestack Tomographic Velocity Inversion System

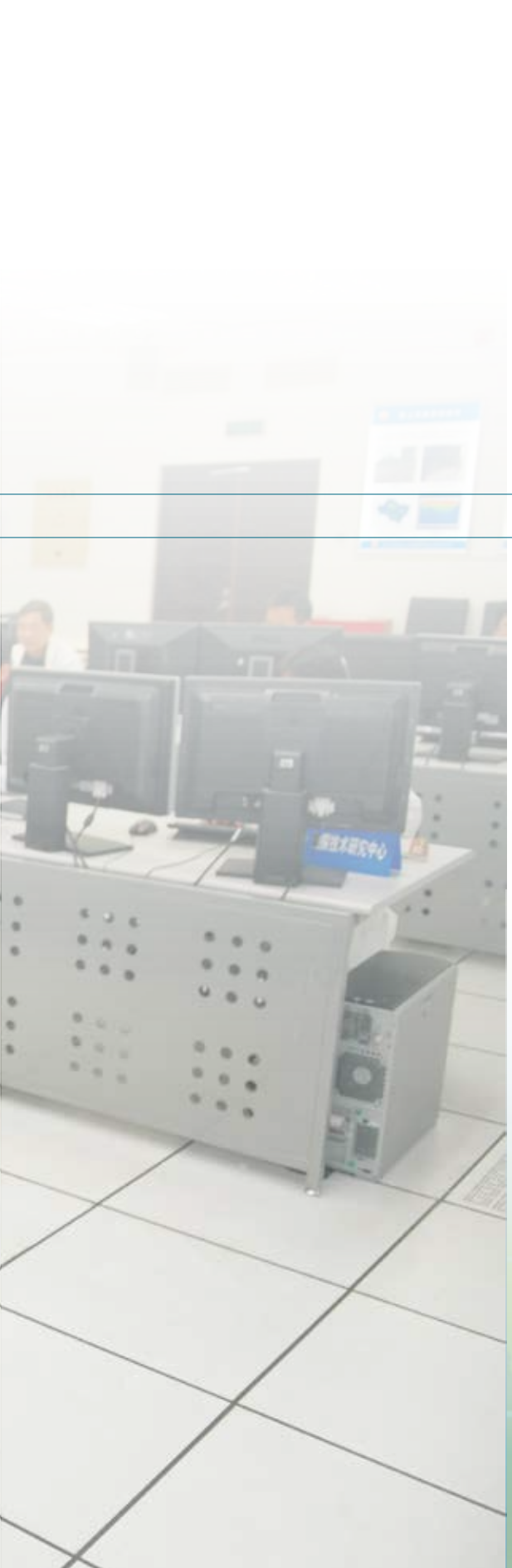
Science & Technology Management Department, CNPC

2015



CHINA NATIONAL PETROLEUM CORPORATION

GeoEast-Tomo : Accurate Imaging of Complex Exploration Areas is Our Goal!



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.

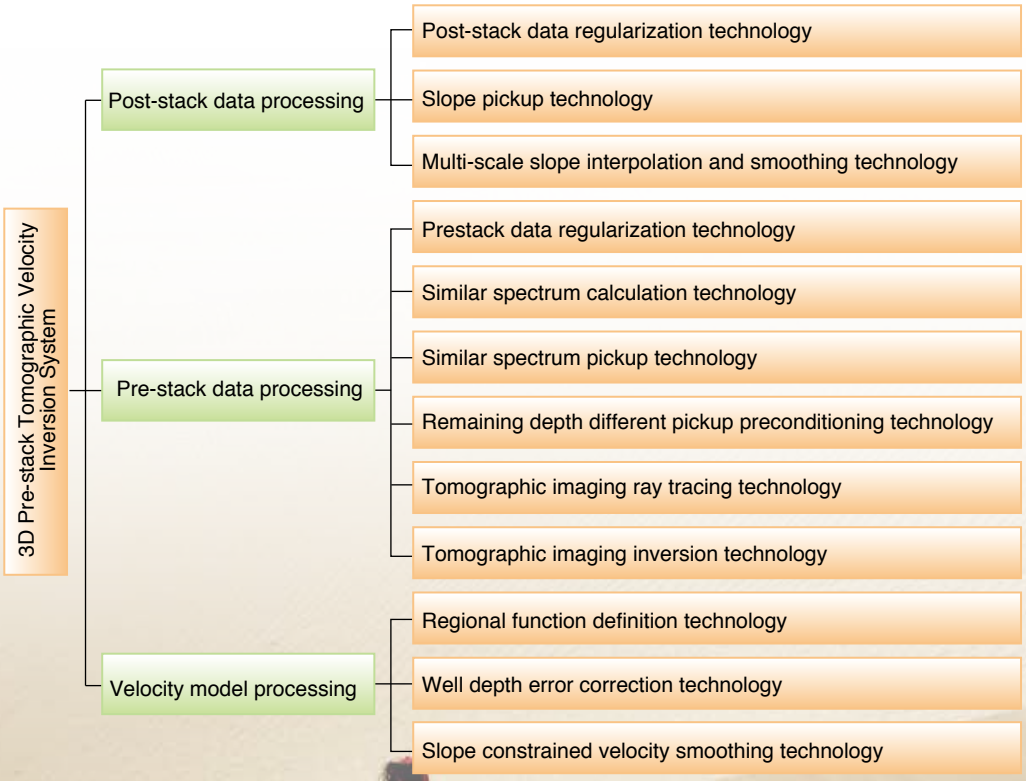
GeoEast-Tomo 3D Prestack Tomographic Velocity Inversion System is one of representatives for major innovations of CNPC.

OFFERING ENERGY SOURCES, CREATING HARMONY

1 INTRODUCTION

Pre-stack depth migration (PSDM) is a processing technology for realizing geologic structure space homing, whereas velocity model establishment is a very important link. Whether the velocity model is correct or its accuracy has a direct impact on migration imaging effect.

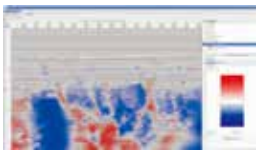
GeoEast-Tomo software developed by CNPC is a multi-function depth domain velocity modeling system using the tomographic inversion technology to optimize velocity model. The system has been developed based on GeoEast platform, is characterized by little manual intervention, quick iteration speed, convenient quality control, etc., and includes the functions such as slope pickup, similar spectrum calculation and pickup, tomographic imaging ray tracing, tomographic imaging inversion, etc. as well as corresponding auxiliary management and quality control means.



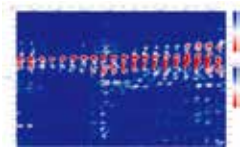
GeoEast-Tomo technology framework

2 MODULE FUNCTIONS

Based on multi-azimuth PSDM outputted CIG and initial migration velocity model, the 3D pre-stack tomographic velocity inversion system calculates similar spectra and performs automatic depth error pickup using CIG. Combining slope information pickup on migration data body, the system performs tomographic imaging ray tracing to build the giant equation set used in velocity inversion; the initial migration velocity model can be updated and TTI-including aeolotropism velocity model can be obtained by solving the equation set via tomographic inversion iteration. Well depth can be used to correct the velocity model during inversion, thus ensuring the correctness of the velocity model.



Slope pickup

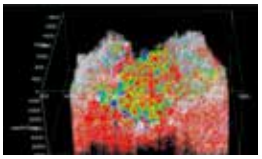


Similar spectrum calculation

Data regularization

GeoEast Tomo Cyclone

Similar spectrum pickup



Tomographic inversion

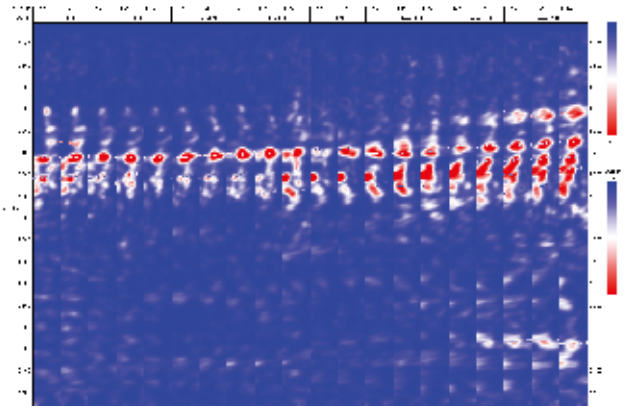
Ray tracing

GeoEast-Lightning system function diagram

3 CHARACTERISTIC TECHNOLOGIES

3.1 Tomographic Inversion Data Matching Preprocessing Technology

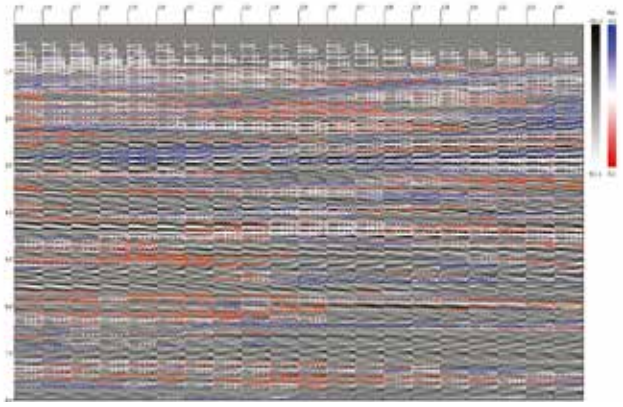
Firstly carry out preprocessing including data regularization etc. of irregular input data to obtain the appropriate data for tomographic inversion and improve the efficiency and accuracy of execution of subsequent processing steps.



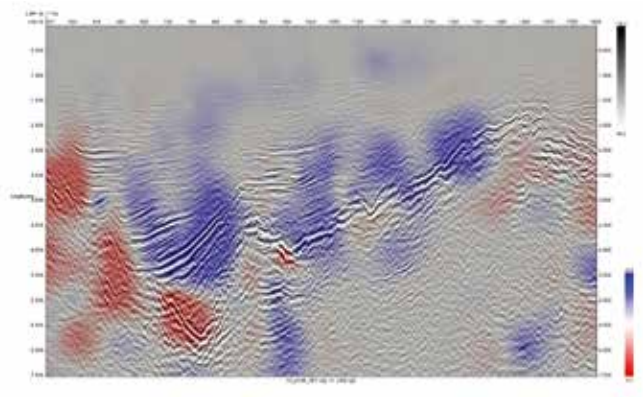
K-Semblance similar spectrum

3.2 Similar Spectrum Gather Calculation and Depth Difference Automatic Pickup Technology

Use the unique K-Semblance (normal similar spectrum) technology to obtain precise velocity similarity spectrum. The system uses multiple parallel technologies to solve the problem on large quantity of similar spectrum gather calculation, thus improving similar spectrum gather calculation efficiency. The automatic pickup technology is used in depth difference pickup, thereby greatly improving processing efficiency.



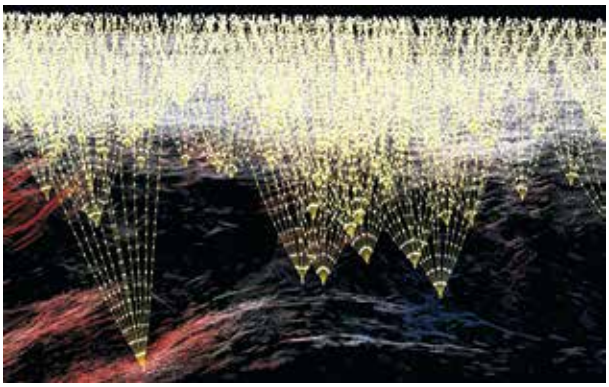
Complex remaining depth difference pickup



Superposed display chart of automatically picked-up stratigraphic dip and profile

3.3 Stratigraphic Dip Automatic Pickup and Multi-scale Dip Interpolation Technology

Reliable stratigraphic dip information is automatically picked up using the energy criterion, and the multi-scale Laplace interpolation technology is used to build the stratigraphic dip field throughout the survey area.

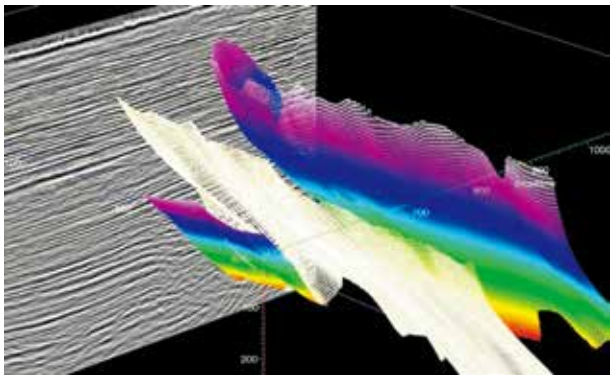


3.4 Tomographic Imaging Ray Tracing and Inversion Equation Set Establishment Technology

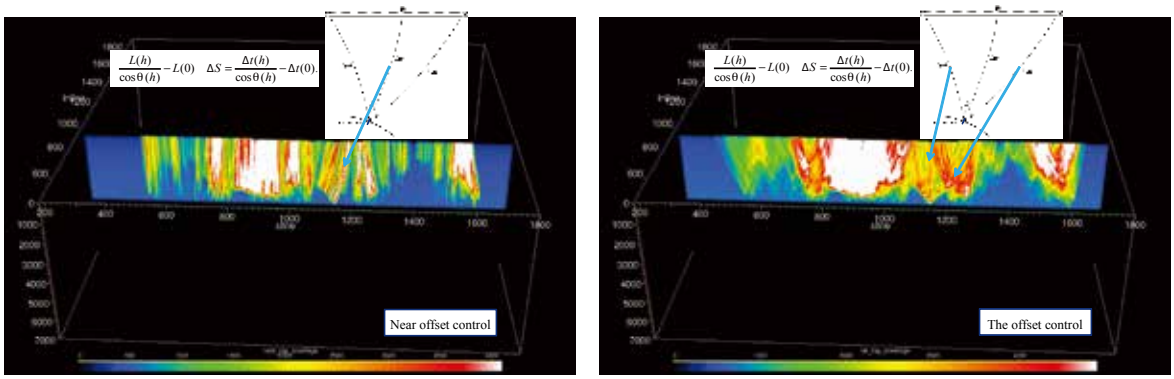
Multi-azimuth data are used to carry out tomographic imaging ray tracing and establish the giant equation set used in aeolotropism velocity model inversion; in addition, preconditioning processing of the equation set is performed to ensure the convergence and reliability of inversion.

3.5 Geologic Model Constrained Tomographic Imaging Inversion Technology

Carry out tomographic inversion using the initial velocity model, remaining depth difference pickup data, 3D stratigraphic slope data and regional definition function, and output a new velocity model. On the basis of inversion, the 3D pre-stack tomographic velocity inversion system can be used to correct the velocity model using drilling location and depth error, thus further improving the reliability and accuracy of the velocity model.



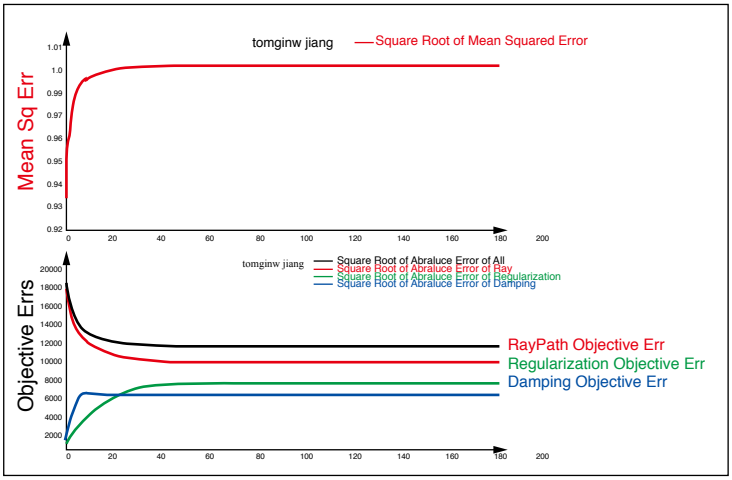
Superposed display chart of automatically picked-up stratigraphic dip and profile



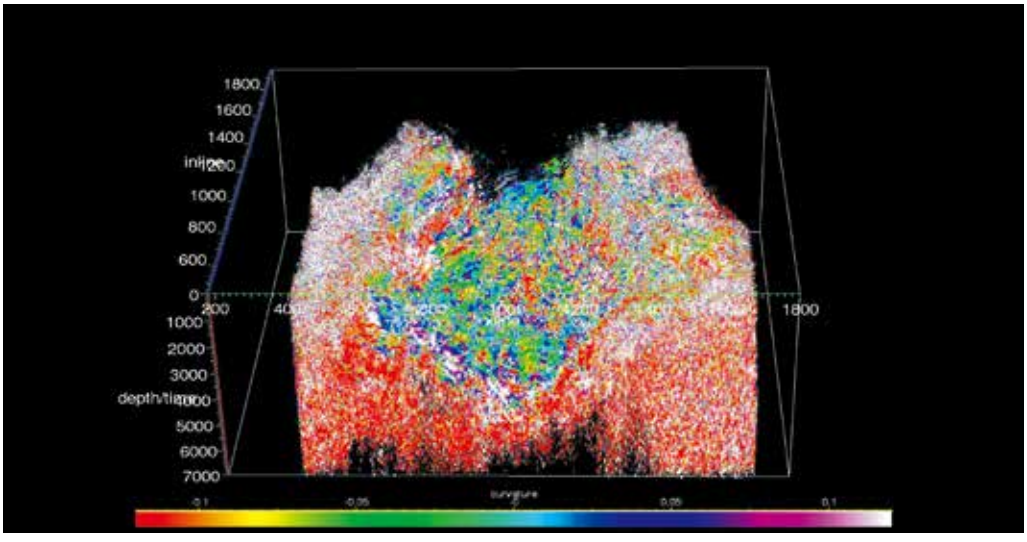
Inversion algorithm chart

3.6 Inversion Quality Control Technology

The 3D pre-stack tomographic velocity inversion system integrates powerful data display tools and provides flexible parameter control technology, and the user can flexibly set parameters and monitor calculation results in each calculation step of the system.



Calculation process convergence quality control chart

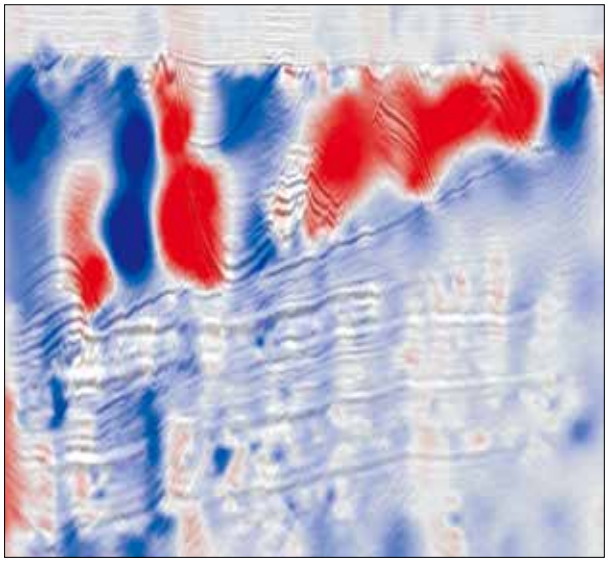


Curvature body monitoring technology after inversion

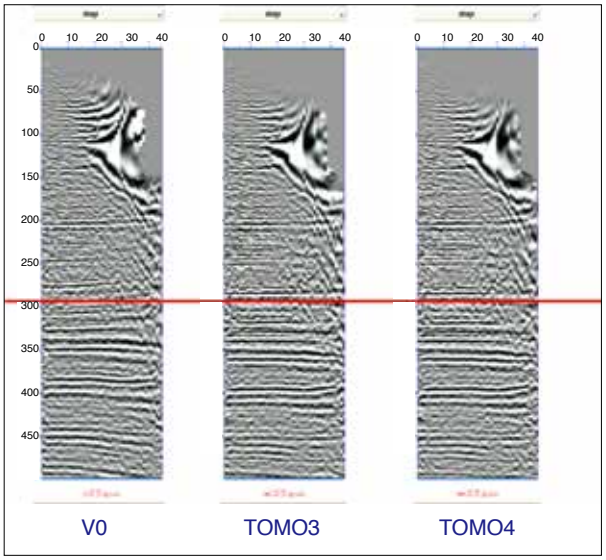
4 TYPICAL CASES

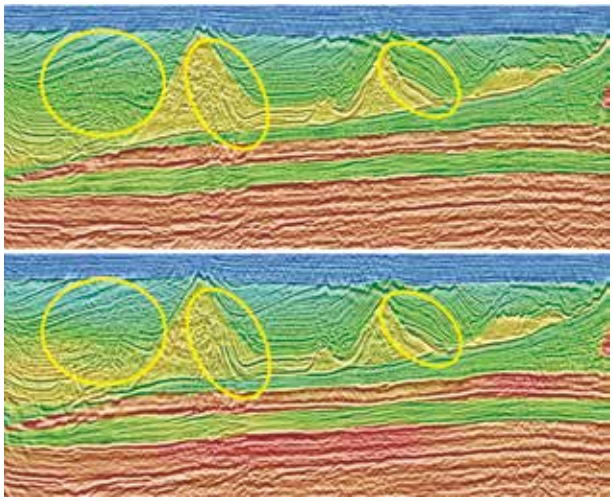
4.1 Caspian Block

Salt dome is a geologic body with high wave impedance. After encountering salt domes, most energy of seismic waves is reflected back to land surface. The reflection waves from seismic acquisition carry the effective information on only a small quantity of subsalt horizon reflections, and subsalt imaging velocity shall be calculated using the known weak effective information from each direction. Therefore, whether subsalt imaging velocity is accurate or not is the key to migration imaging success. Caspian 3D survey area is a salt dome development area in a country. According to the comparison of imaging results before and after velocity updating using the 3D pre-stack tomographic imaging modeling system, the RTM imaging result after velocity updating depicts salt dome boundaries more clearly, realizes more continuous subsalt imaging and leads to smaller noise in salt domes.

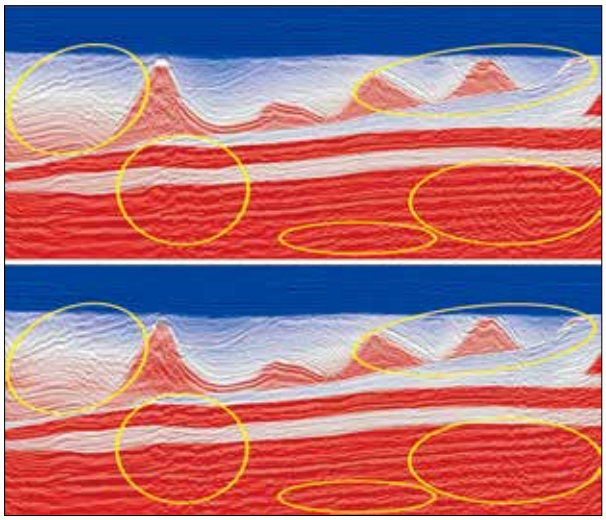


Superposed display chart of automatically picked-up Xdip and profile





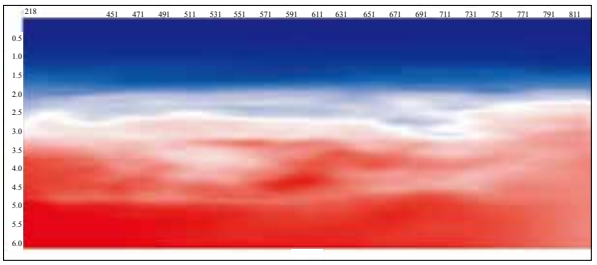
Comparison chart of RTM imaging results at different velocities
(Upper: velocity before updating, lower: velocity after updating)



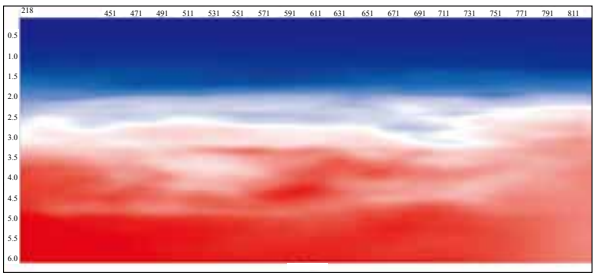
Comparison chart of WEM imaging results at different velocities
(Upper: velocity before updating, lower: velocity after updating)

4.2 Qikou Block

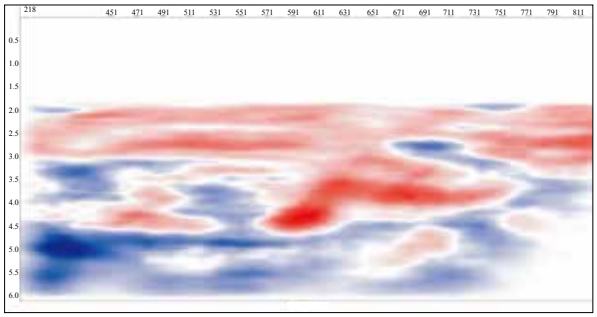
Imaging of complex fault blocks is the difficulty in seismic imaging in Eastern China. The difficulty in complex fault block imaging lies in accurate depiction of fault block boundaries and depiction of section extensibility. Wide-azimuth data are especially effective to imaging of complex fault blocks, and the migration of wide-azimuth especially needs TTI velocity model. The 3D pre-stack tomographic imaging modeling system can use multi-azimuth migration data gathers to carry out inversion of TTI velocity model; after using the updated TTI velocity model, imaging of complex fault blocks has been improved remarkably.



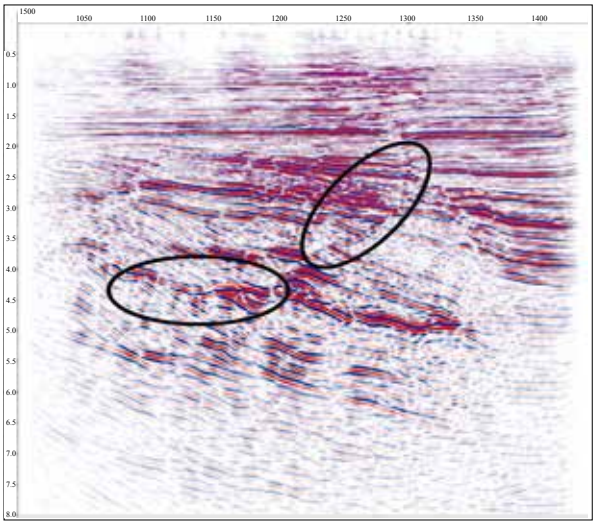
Velocity before updating



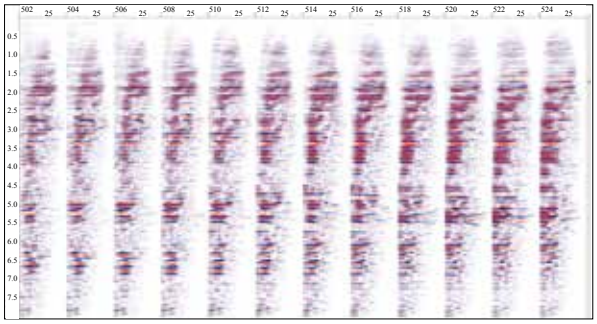
Velocity after updating



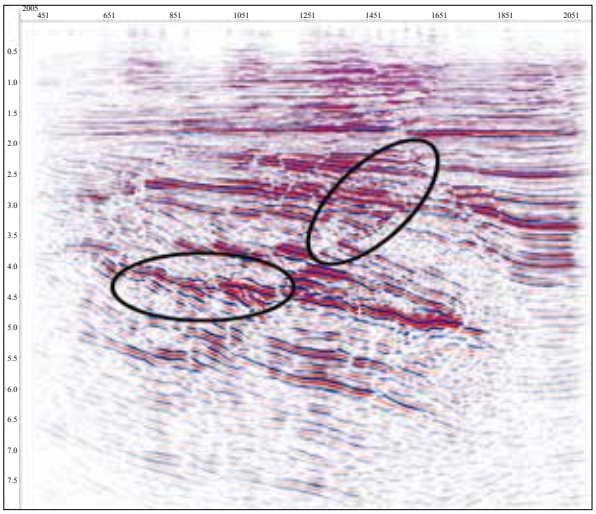
Velocity variation



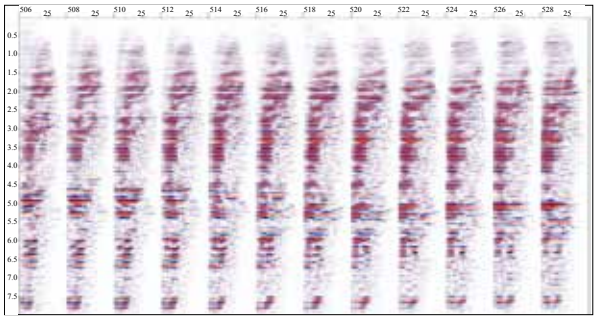
RTM imaging before velocity updating



RTM angle gather before velocity updating



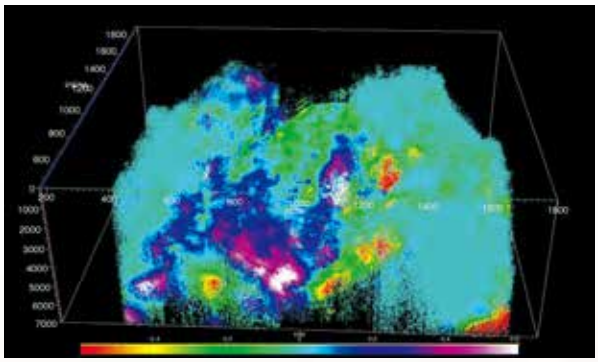
RTM imaging after velocity updating



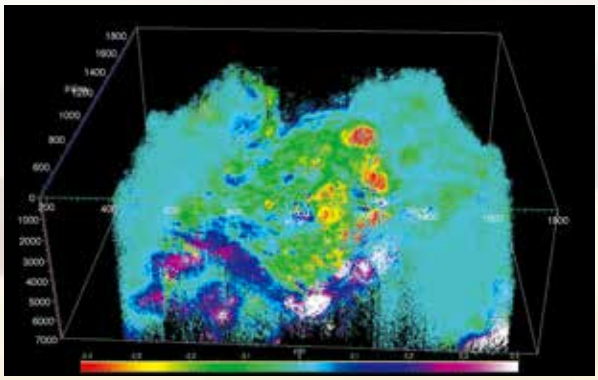
RTM angle gather after velocity updating

4.3 Damintun Block

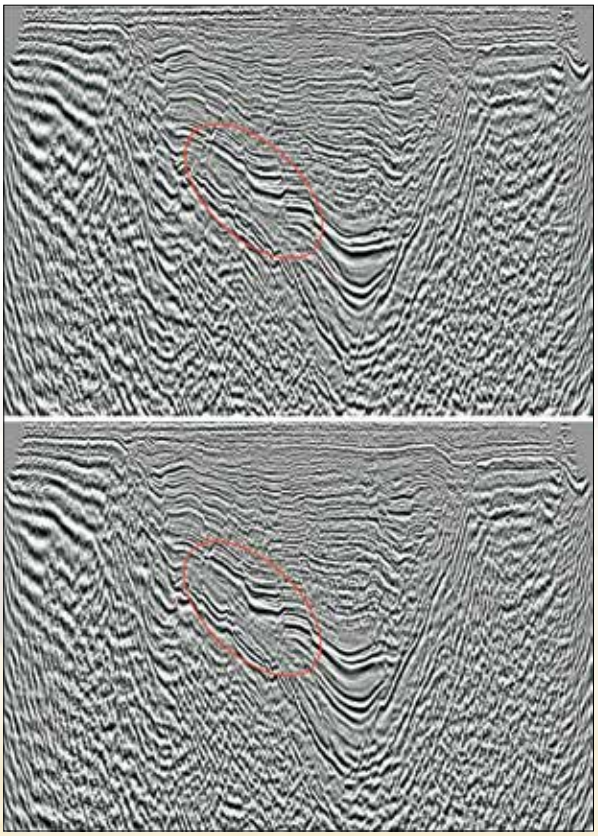
The development potential of mature reservoirs in old oilfields has been completely tapped, and there is a must for finding new reservoirs. Large dip slope belts are important potential control regions. The imaging capacity is limited and especially there is a large information error of the velocity in these formations, so that the geologic conditions of these regions are not very clear, thus affecting oilfield development. Typical slope belts are developed in Damintun sag in Liaohe oilfield in China. After velocity updating using the 3D pre-stack tomographic velocity inversion system, the RTM imaging result quality of large dip slope belts has been improved remarkably.



Xdip X slope quality control



Xdip X slope quality control



Imaging comparison before and after tomographic velocity optimization

5 SCIENTIFIC RESEARCH EQUIPMENT

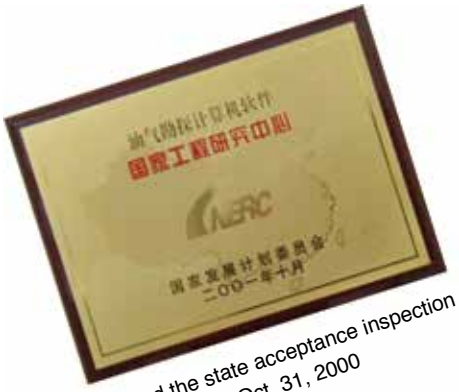
Research & Development Center, BGP Inc., CNPC has a high performance parallel cluster, which has totally 20790 CPUs with 76458 cores and 824 GPUs with 470000 cores, with the FLOPS of 1497Tflops and the total storage capacity of 20000TB.

High performance parellel computer clastor

large termind eqalpment 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 level 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

Dai Nanxun

Doctor, professor. Since joining CNPC BGP in 2009, he has actively studied and developed frontier technologies in the seismic wave imaging and velocity inversion field leading the team. The GeoEast-Lightning software developed by the team led by him has filled up multiple technology gaps in the depth domain migration imaging field of CNPC.
Tel: 010-82072020-3018
Email: nxdai@bgprdc.com

Zhang Xudong

Senior engineer. He has been engaged in R&D of geophysical exploration software. He once participated in R&D of multiple ministerial and bureau-level projects and takes charge of R&D of interactive framework, system software and high performance calculation software.
Tel: 0312-3825132
Email: zhangxud@cnpc.com.cn

Geng Weifeng

Senior engineer. He is engaged mainly in the study of exploration and seismic data processing methods and software development and concentrates on the study of exploration and seismic data velocity analysis technologies and VSP processing technologies and software development. He has obtained 3 patents, and 6 papers written by him have been published.
Tel: 0312-3825948
Email: gengweifeng@cnpc.com.cn

Wu Wei

He is engaged mainly in the study of depth migration and depth domain modeling method. He joined GeoEast-TOMO project group in 2009 and his main task is method research, module development, software testing, etc.
Tel: 010-82072020-3162
Email: weiwu@bgp.com.cn

Liu Jianhong

Senior engineer, doctor. He is engaged mainly in seismic data processing technology research and has completed over 20 complex region seismic data research projects.
Tel: 0312-3824067
Email: liujianhong@cnpc.com.cn

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技术依托单位联系人：

白雪莲　女士

电　话：0312-3737215

Email: Baixl1@cnpc.com.cn

中国石油科技管理部联系人：

刁　顺／窦红波　先生

电　话：86-10-59986059/59982528

Email: sdiao@cnpc.com.cn/ douhb@cnpc.com.cn

Contact of the Technical Support Unit :

Ms. Bai Xuelian

Tel: 0312-3737215

Email: Baixl1@cnpc.com.cn

Contact of Science&Technology Management Department,CNPC :

Mr. Diao Shun/Dou Hongbo

Tel: 86-10-59986059/59982528

Email: sdiao@cnpc.com.cn/ douhb@cnpc.com.cn