



PAI Technology

Integrated Seismic Acquisition-Processing-Interpretation

Science & Technology Management Department

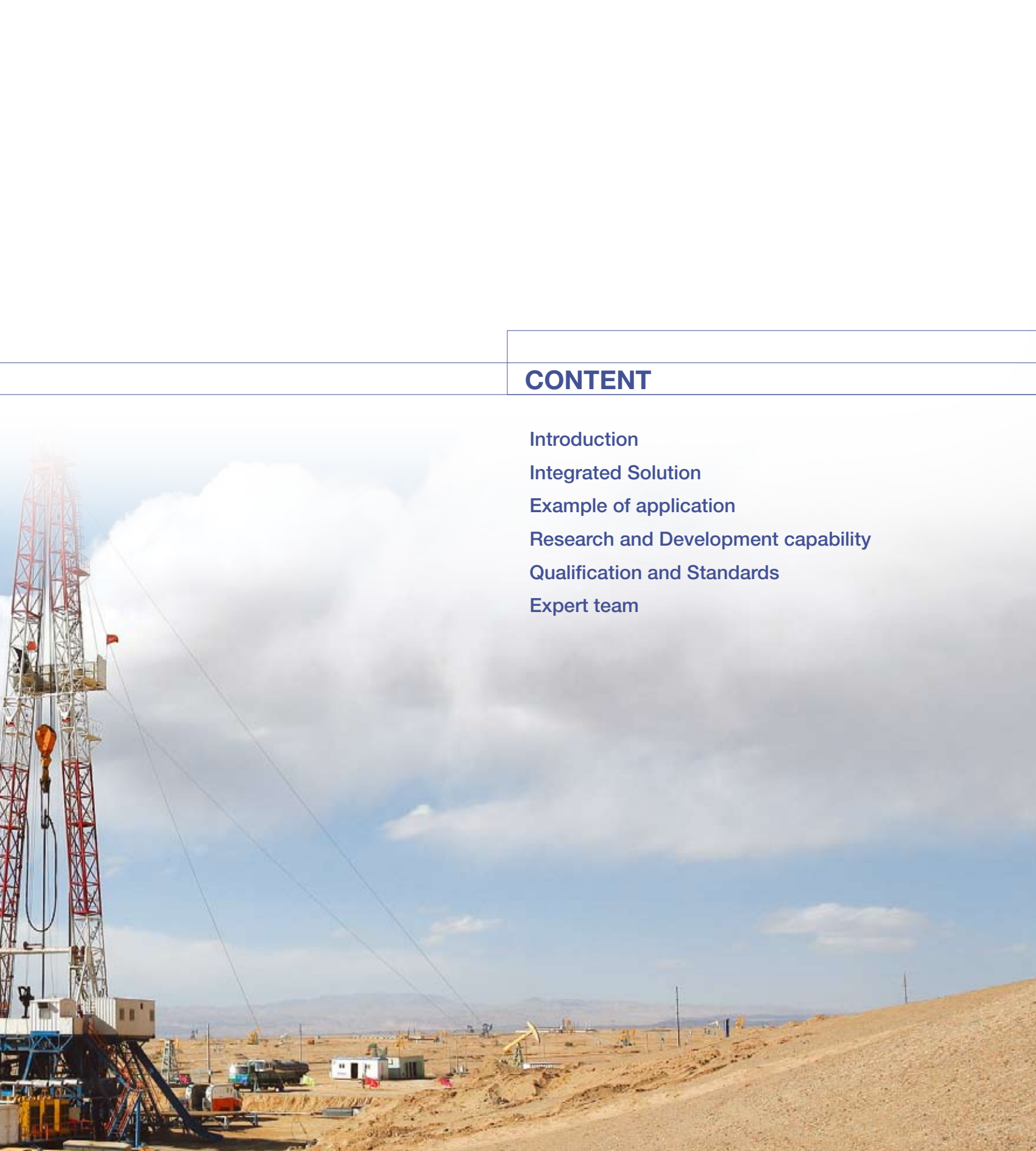
■ 2011



CHINA NATIONAL PETROLEUM CORPORATION

*Keep Active Innovation
Offer Integrated Solutions*





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China National Petroleum Corporation (CNPC) is a state-authorized investment agency and a state holding company. As an integrated oil company of cross-regions, cross-industries and cross-countries, it adopts modern enterprise system to realize the integration of upstream and downstream operations, internal and external trade and production and marketing. CNPC has 17 upstream companies, 33 downstream companies and 36 large-scale marketing companies. It is China's largest producer and supplier of oil and gas, and also of refined oil products and petrochemicals. In 2010 CNPC produced 105 million tons of crude oil and 72.5 billion cubic meters of natural gas, while crude processing volume reached 135 million tons. The total revenue of RMB1,720 billion with a profit of RMB172.7 billion had been achieved the same year. Its profit is among the highest of the domestic enterprises in China.

CNPC was ranked 10rd in Fortune Global 500 in 2010 and 5th among global top 50 oil companies.

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 Integrated Solution of Seismic Data Acquisition, Processing and Interpretation (PAI), is just one of the representative major innovations of CNPC.



1 Introduction

With CNPC's geophysical prospecting experiences of many years

PAI Technology (PAI) integrates the latest achievements of continuous innovation and practices for geophysical prospecting.

PAI can provide the integrated solution of seismic data Acquisition, Processing and Interpretation to face with different kinds of challenges in oil and gas exploration and development.

PAI Technology includes:

PAI-Mountain, The Integrated Solution of Seismic Exploration for Mountain

PAI-Desert, The Integrated Solution of Seismic Exploration for Desert

PAI-TZ, The Integrated Solution of Seismic Exploration for Transition Zone

PAI-Loess, The Integrated Solution of Seismic Exploration for Loess

PAI-IRS, The Integrated Solution of Seismic Exploration for Inland Oil/gas Rich Area

PAI-LRC, The Integrated Solution of Seismic Exploration for Inland Reservoir Characterization

PAI-GEM3D, The Integrated Solution of Seismic Exploration for 3D-GEM



Mountain

The Integrated Solution of Seismic Exploration for Mountain

Being aimed at characteristic surface and underground conditions of foothill belts in complex mountains, CNPC has developed multiple types of advanced devices and equipment, such as large-tonnage controllable seismic sources, mobile drill rigs, portable mountainous drill rigs etc. The Integrated solution of seismic prospecting for Mountain area (PAI-Mountain) is developed and formed, which has seismic prospecting capability in different forms of complex mountain terrain condition below relative relief 2000m. CNPC provides high quality services to many oil companies in the area of Western China and abroad with this set of technology.





Technical solution:

- Research and development, manufacture and application of assorted devices for mountain seismic prospecting
- Layout measurement and quality monitoring techniques with Seis and SSOffice being carriers
- Combined shooting and operation of multifold seismic source in different surface conditions
- Mixed style pattern layout and dynamic analysis techniques
- Combined static correction technique based on model restricted first break inversion
- Wavelet shaping, signal separation, and pre-stack depth migration technique based on relief surface
- Velocity model-building, structure model-building and depth domain interpretation techniques

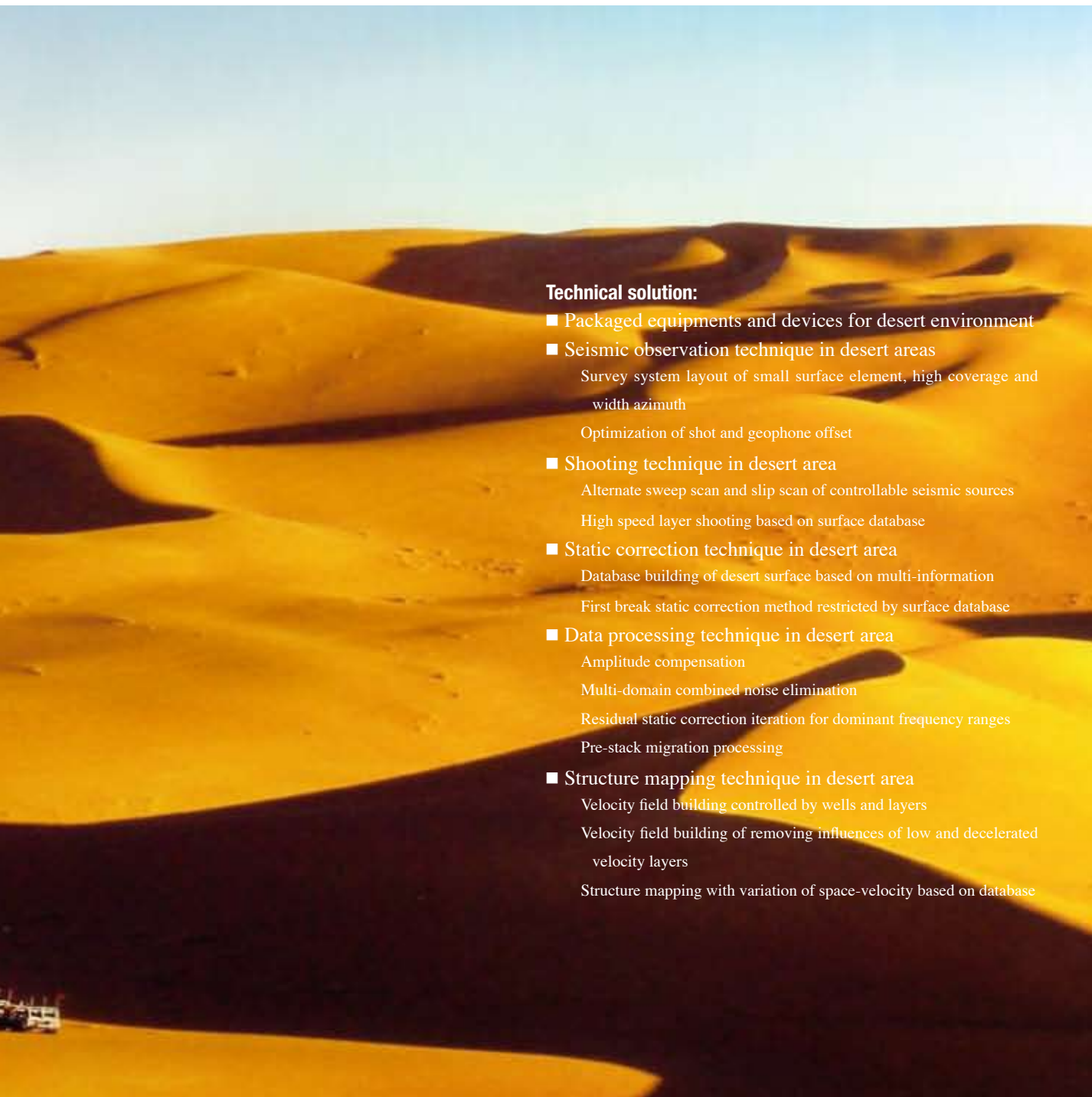


Desert

The Integrated Solution of Seismic Exploration for Desert

Being aimed at the features of desert surface and underground, and to solve absorption attenuation of seismic signals, statics, low signal-to-noise and low resolution problems etc., CNPC dedicates to research and application of seismic data acquisition, processing, interpretation techniques and assorted prospecting devices, and forms the integration solution, PAI-Desert, which could solve complex trap oil and gas exploration problems of large depth, low relief structures etc. in the condition of desert area. PAI-Desert has been successively applied in the famous deserts of Taklamakan, Gurbantunggut, Kumutage, Sahara, Middle East etc., to provide oil and gas prospecting services to many oil companies both abroad and home.





Technical solution:

- Packaged equipments and devices for desert environment
- Seismic observation technique in desert areas
 - Survey system layout of small surface element, high coverage and width azimuth
 - Optimization of shot and geophone offset
- Shooting technique in desert area
 - Alternate sweep scan and slip scan of controllable seismic sources
 - High speed layer shooting based on surface database
- Static correction technique in desert area
 - Database building of desert surface based on multi-information
 - First break static correction method restricted by surface database
- Data processing technique in desert area
 - Amplitude compensation
 - Multi-domain combined noise elimination
 - Residual static correction iteration for dominant frequency ranges
 - Pre-stack migration processing
- Structure mapping technique in desert area
 - Velocity field building controlled by wells and layers
 - Velocity field building of removing influences of low and decelerated velocity layers
 - Structure mapping with variation of space-velocity based on database

PAI TZ **The Integrated Solution of Seismic Exploration for Transition Zone**

In view of the complex and versatile features of seismic prospecting in shallow sea and transition zone, CNPC accumulates abundant seismic prospecting experiences, and forms the integration solution of PAI-TZ with a core of the packaged devices and the characteristic techniques of acquisition and processing. PAI-TZ realizes no-seam joining of seismic data with different surface types in shallow sea and transition zone and is able to solve well the seismic prospecting problems in shallow sea and transition zone.

With leading seismic prospecting technique in shallow sea and transition zone, CNPC successively provides technical services for exploration and development many oilfields in-home and oil companies abroad such as Unocal, Saudi Aramco, Shell etc.

Technical solution:

- Packaged devices for seismic data acquisition in shallow sea and transition zone
 - Air-gun seismic source systems for shallow sea
 - Seismic drilling devices
 - Equipment of cable draw-off gear and matched carrier
- Seismic data acquisition technique in shallow sea and transition zone
 - Acquisition design
 - Allocation of shooting and receive points
 - Multi-system combined shooting and receiving
 - Overall quality control
- Seismic data processing technique in shallow sea and transition zone
 - Surface conformability processing
 - Wavelet shaping processing
 - OBC processing
 - Attenuation of high frequency noise and external source noise







Loess

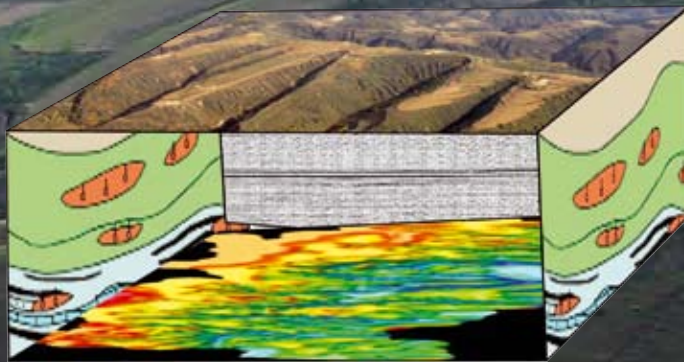
The Integrated Solution of Seismic Exploration for Loess

Loess area has very particular landform where plateaus, flat-topped ridges, ditches, replats, slopes are well developed and co-existed. The overlying soil is arid and loose, with loess thickness changed severely, thereby results in various problems of low velocity, serious absorptive attenuation of seismic waves, strong homogeneity of media, and bad shooting and receiving conditions. In view of these problems, CNPC has developed a series of characteristic techniques such as tortuous lines and ditch-ridge connection prospecting, 3D anomalistic prospecting, erosion surface depiction, lithologic identification for thin interbeddings etc. PAI Loess has been formed and has the capability to solve the problems of low porosity, low permeability, low abundance, thin interbeddings, lithologic oil reservoir exploration and development under tremendous thickness background of loess.



Technical solution:

- Tortuous line and ditch-ridge connection prospecting technique
- 3D Anomalistic prospecting technique
- Refraction static correction technique of first break iteration in four domains
- Noise attenuation and high accuracy coherence superposition processing technique
- Fine depiction technique of erosion surface
- Prediction technique of reservoir physical properties and oil/ gas-bearing
- Optimization technique for superposition well locations





IRS

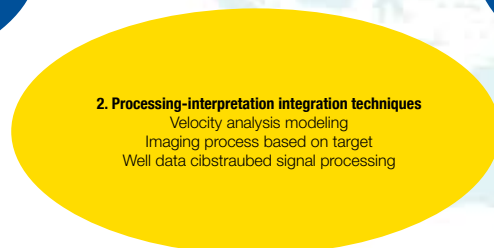
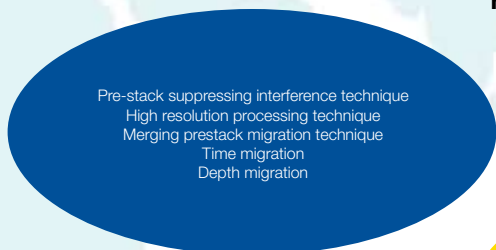
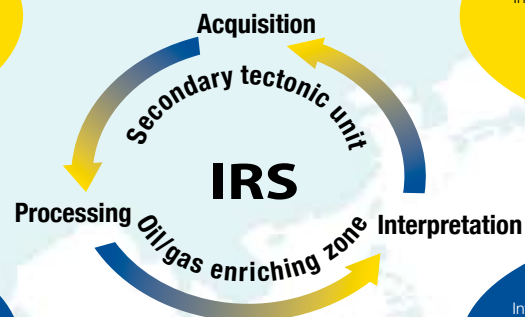
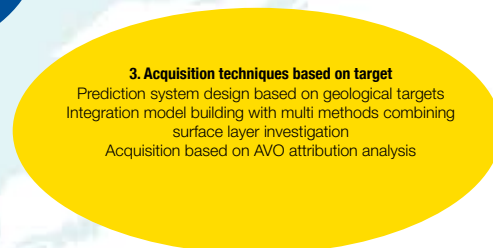
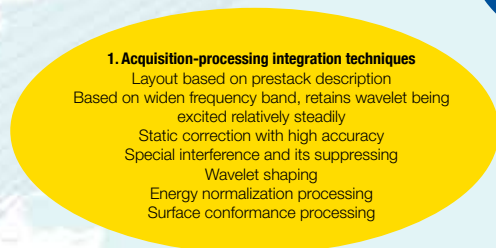
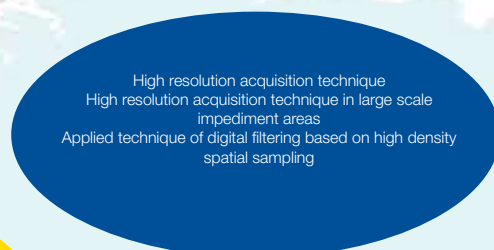
The Integrated Solution of Seismic Exploration for Inland Oil/gas Rich Area

In view of multilayer formation lithologic traps, complex fault blocks, low relief structures, thin reservoirs, deep buried hills in oil gas enriching areas and data blanking zone caused by large obstruction areas (such as complex urban areas, mine fields, large area waters etc.), PAI-IRS can provide stereo exploration.

Conventional 3D seismic technique is hardly to meet the demand of deepening exploration; it is required urgently to enhance the accuracy of 3D seismic data. Hence, CNPC develops and forms The Integrated Solution of Seismic Exploration for Inland Oil/gas Rich Area (PAI-IRS) with a core of 3D high accuracy seismic prospecting.

Technical solution:

- 3D high accuracy seismic acquisition techniques with characteristics of small surface element, high multifold and width azimuth, increases resolving ability to geological goodies.
- Processing techniques with “high signal-to-noise ratio, high resolution, high fidelity” being target and merging prestack time migration or prestack depth migration as dominant, forms unified 3D seismic data volume with high accuracy in whole area.
- With the means of high accuracy sequence stratigraphy, prestack and poststack inversions, whole 3D visualization, carries on fine interpretation of seismic data, realizes entirety evaluation in whole area and trap description, enhances the precision prediction of reservoirs and oil-gas accumulations.

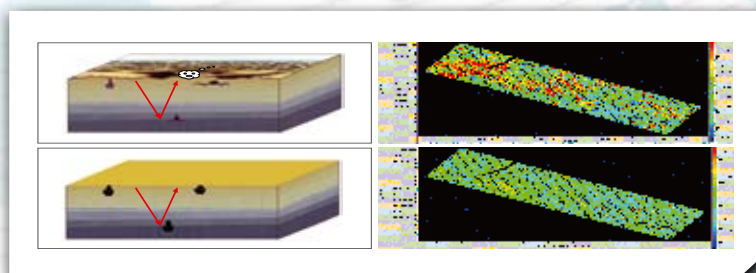
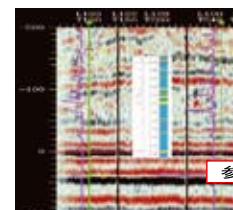




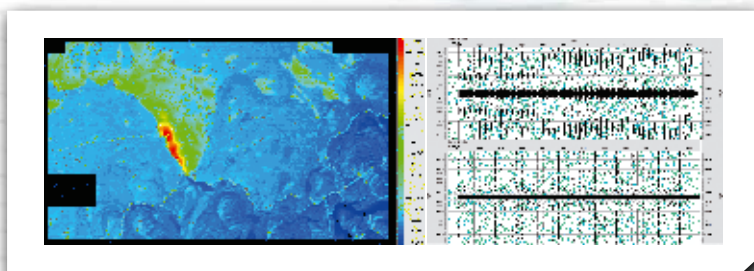
LRC

The Integrated Solution of Seismic Exploration for Inland Reservoir Characterization

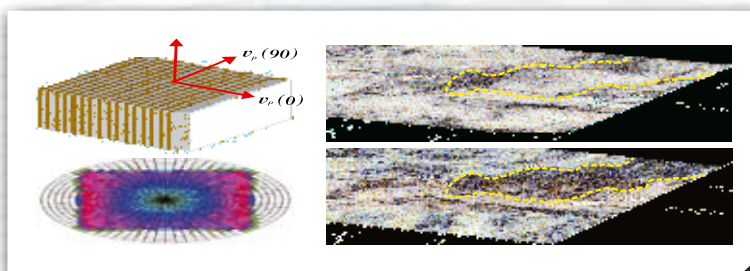
In view of seismic prospecting for land facies thin reservoirs, CNPC researches and develops and forms inland seismic reservoir description integration solution (PAI-LRC), including surface 3D, 3.5D, 4D seismic technique series and VSP, cross-hole seismology series, can effectively solve the oilfield development problem about continental deposit (less than 1/4 wave length) thin interbed reservoirs.



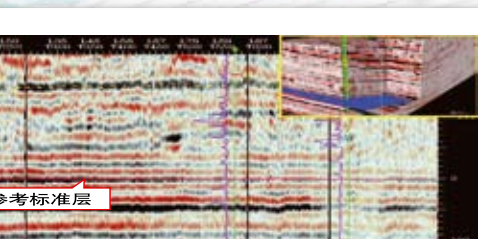
High accuracy processing technique for relative retention amplitude, frequency, phase and waveform



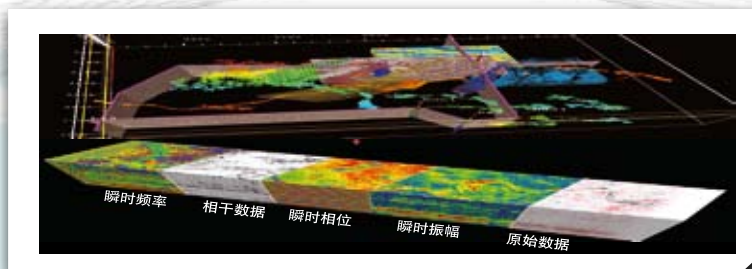
Quality monitoring technique for seismic acquisition, processing



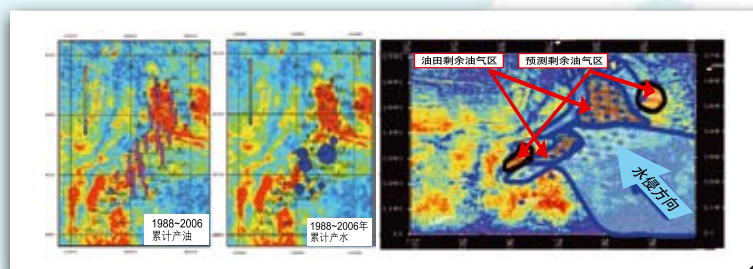
Whole (Width) azimuth seismic acquisition technique



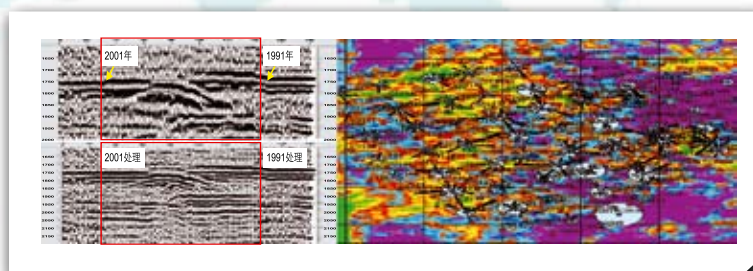
Relative calibration and structural evolution interpretation technique--Reference marker bed



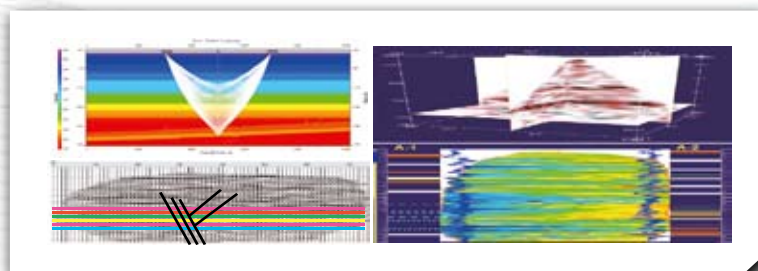
Sedimentary evolution interpretation technique for thin reservoirs



3.5D synthetically seismic exploration technique--Direction of flow



4D Non-repeatability seismic exploration technique



Well seismic profile exploration technique



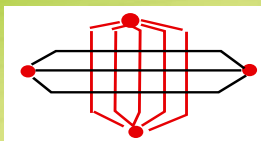
GEM3D

The Integrated Solution of Seismic Exploration for 3D-GEM

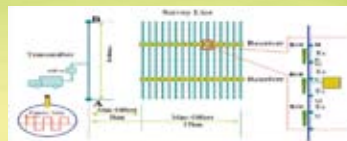
PAI-GEM3D is developed to solve following problems:

- (1) Use of the multi-characters of rocks, such as density, magnetic capacity, resistivity, polarizability, velocity etc.
- (2) Select the different method combination and applicable survey grids.
- (3) Carry out the 3D time-frequency electromagnetic method, and wellhole-surface electromagnetic prospecting.
- (4) Fulfill the visualization processing in GeoEast platform.
- (5) Realize the interfusion of multi-information.
- (6) Provide 3D gravity and electromagnetic integration solution.
- (7) Fit for the complex land surface, complex underground structural zone, specially geological targets such as igneous rocks etc., and hydrocarbon detection and target monitoring.
- (8) Solve better the complex oil/gas exploration problems.

3D acquisition



3D gravity and magnetism acquisition technology with highly dense base point vertical and horizontal observation



High power time frequency electromagnetism 3-D acquisition technique

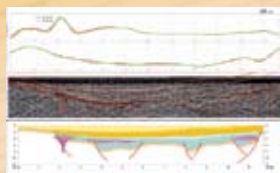


Time frequency electromagnetism acquisition technique in surface 3D survey grids with radial source exciting

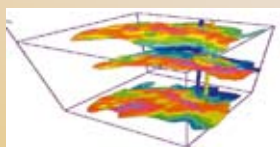


Small bin 3D CEMP acquisition technique

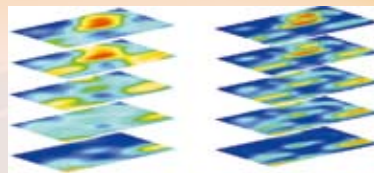
3D processing



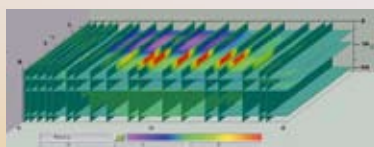
3D gravity stripping technique with constraint of seismic and wells



3D apparent density, apparent magnetic susceptibility inversion technique

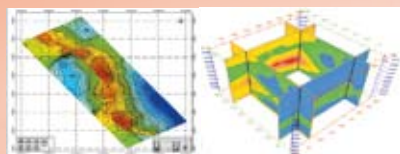


3D electromagnetism processing and static state displacement correction techniques for complex land surface

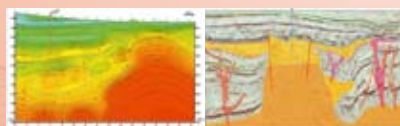


3D CEMP technique

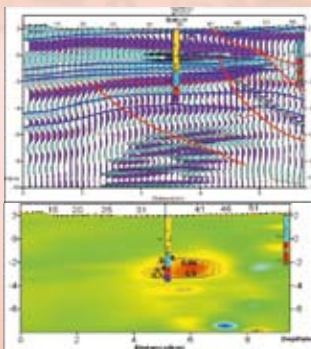
Comprehensive interpretation



GeoEast gravity, magnetism, electrical and seismic 3D visualization comprehensive interpretation technique



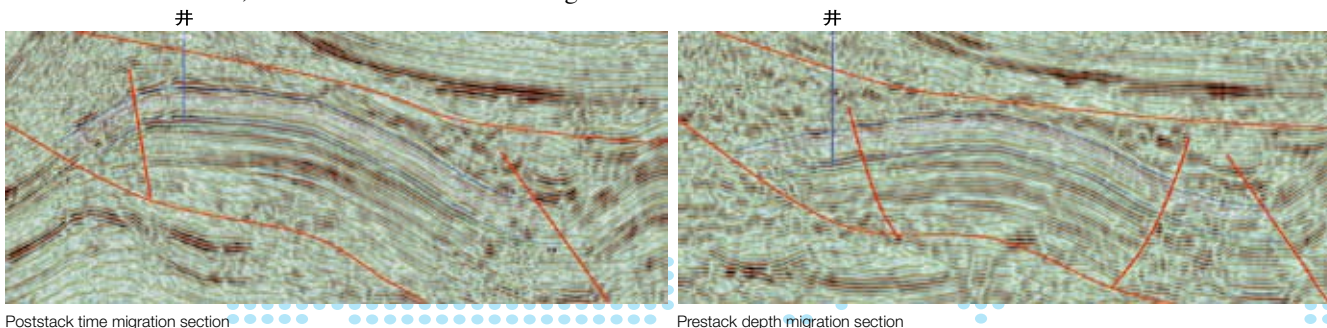
Fuzzy cluster identification and interpretation technique of gravity, magnetism, electrical and seismic for igneous rocks



IPA interpretation technique with 2D oil/gas reservoir electric anomaly model

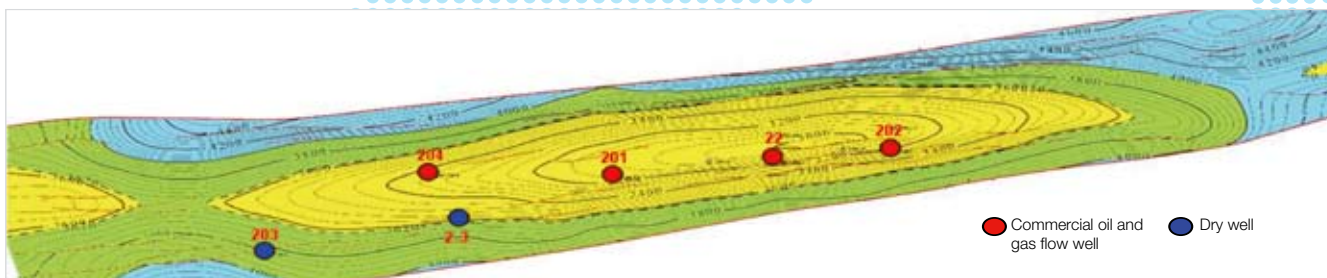
Example 1

PAI-Mountain technique has provided successively the high- quality mountain seismic prospecting services to oil companies both abroad and home, and discovered some oil and gas fields.



Poststack time migration section

Prestack depth migration section

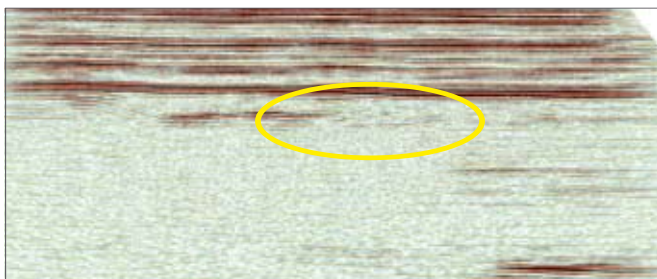


Paleogene top surface structural map (Prestack depth migration)

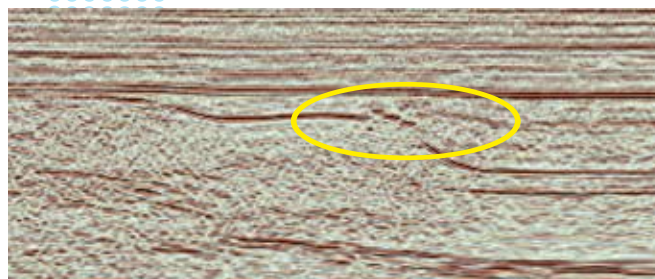
In the exploration of X area, guiding with structure model building, PAI Mountain proceeds directly the geological interpretation in depth domain with prestack depth migration data. It is confirmed by many wells that the accuracy errors in structural maps are all less than 10m.

Example 2

The application effects of PAI-Desert technique in Takelamagan Desert are show as below (lift: before application, right: after application). After application of the technique, data quality is improved qualitatively, and an ultra-giant Ordovician reef oilfield of hundred-million tons was discovered



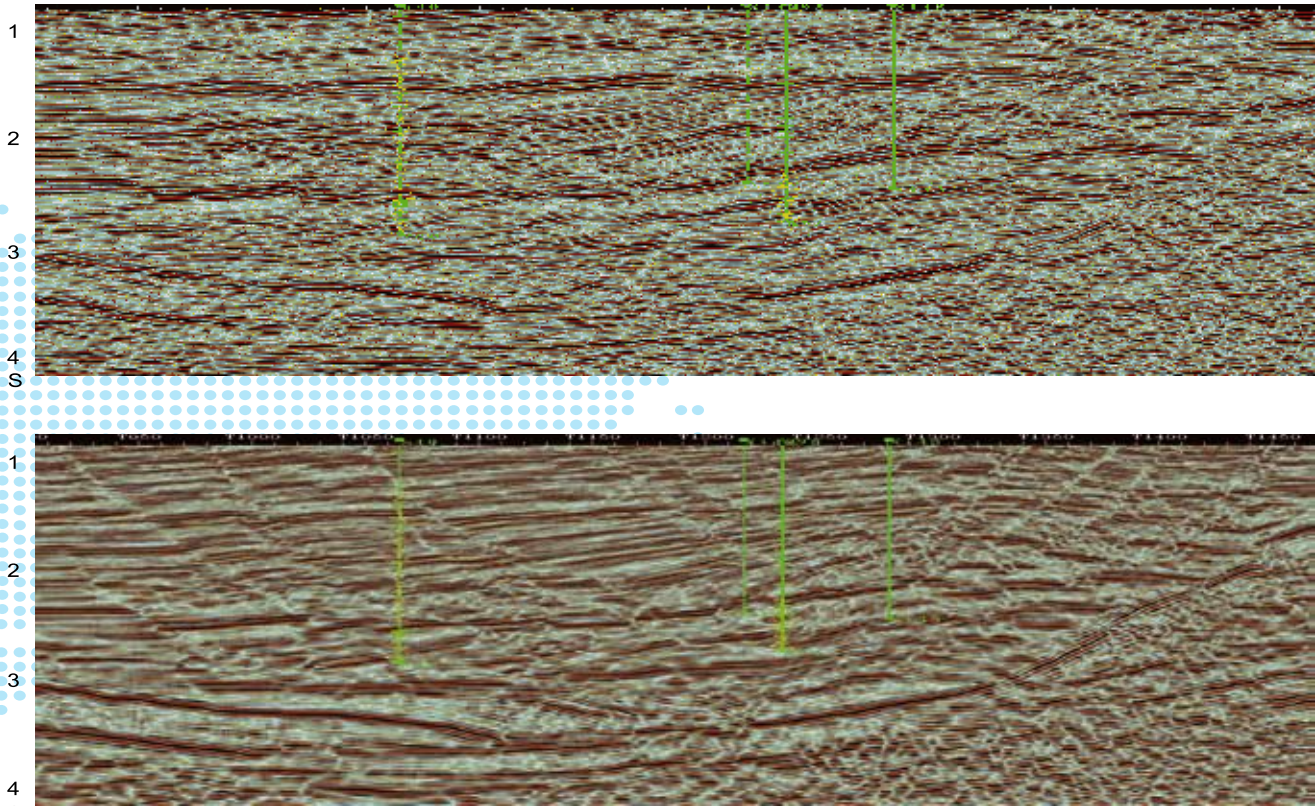
Before application, interpreted as a fracture zone



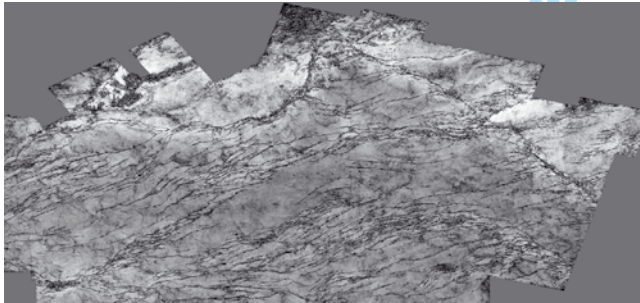
After application, interpreted as a marginal zone of a platform

Example 3

PAI-IRS is applied to the fine oilfield exploration in the Eastern China that effectively impulses the exploration discoveries in Eastern and Middle area of Hebei Province, and Qikou areas etc.



Normal 3D (upper) and IRS 3D (down) seismic profile correlation



Coherence time slice after merging

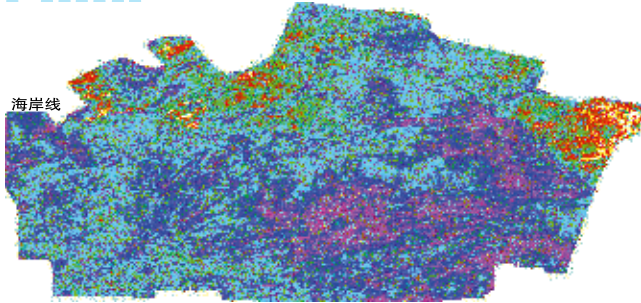
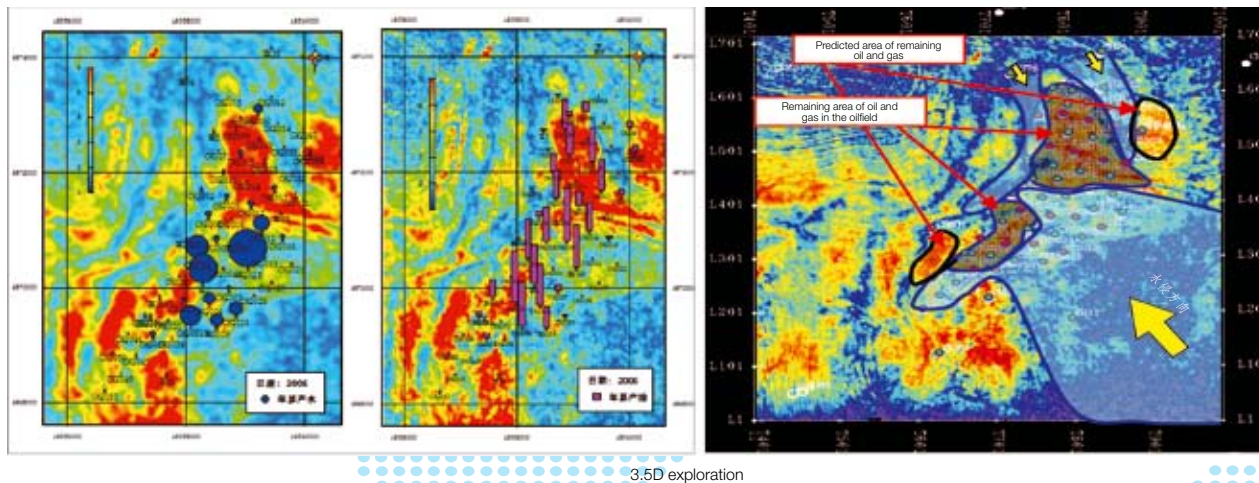


Chart of pure wave amplitude attribute for final offset data after merging

PAI EXAMPLE OF APPLICATION

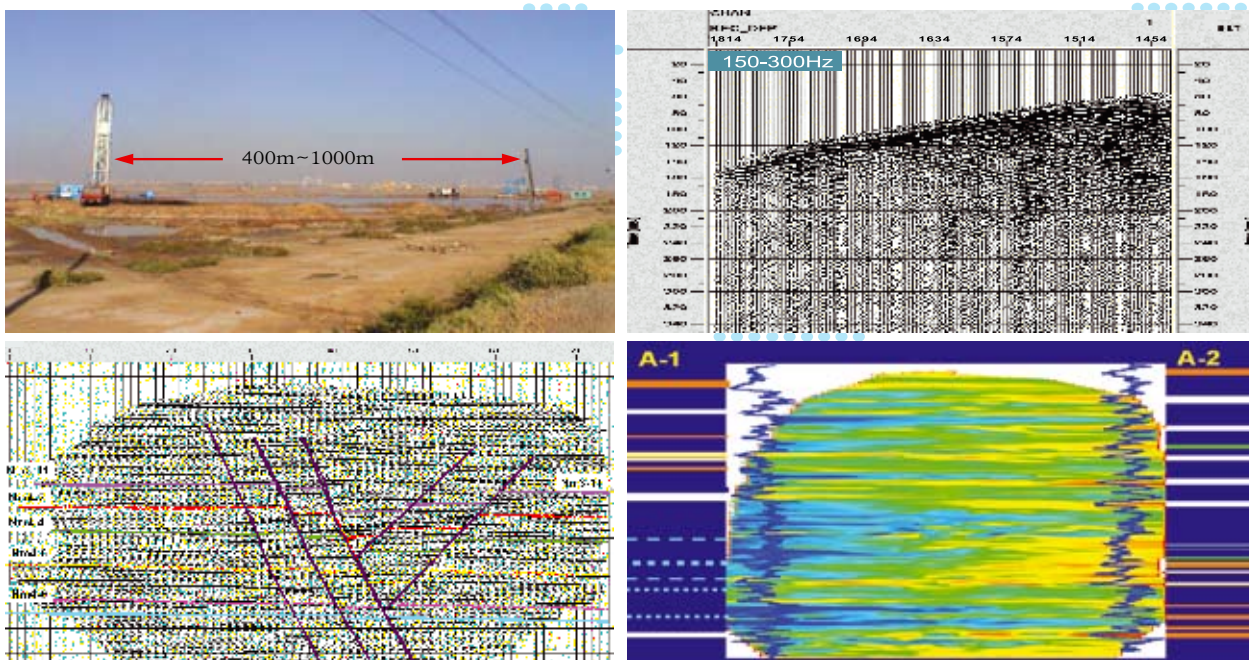
Example 4

PAI-LRC 3.5D technique is applied in the northwest margin of Zhunger Basin; it provides effective information for oilfield development and the distribution prediction of remaining oil.



Example 5

PAI-LRC cross-well VSP seismic technique is applied in oilfield area.



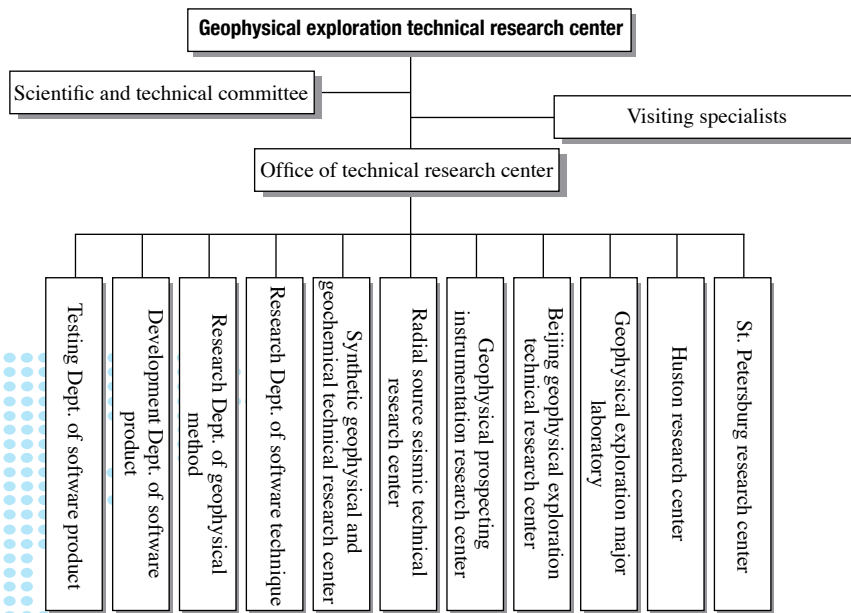
CNPC owns the largest center in China for geophysics, geologic research and software development, The National Engineering Research Center of Oil and Gas Exploration Computer Software, approved by National Development and Reform Commission. Its research and development activities include each sector of geophysics and geology.

There are more than 280 full-time researchers who engage the research of geophysical and geologic methods and software development, hereinto, 1 academican in Chinese Academy of Engineering, 8 technologists of top grade, and 50 technologists. There are parallel computer clusters with over 1000 computation nodes, more than 200 sets of high-end servers, concentrated storage devices, image terminals in the center. The efficiency for method research and software development in the center is super high.

Geological method research- Using seismic stratigraphy, sequence stratigraphy, lithology seismology methods etc., the structural trap, stratigraphic trap, unconformity trap and different kind of reservoirs with hidden complex types of traps were researched and evaluated. The integrated geologic investigation level is the domestic leading; the sequence stratigraphy technique etc. has reached the international advancement rank. In view of the complex geologic condition of surface and subsurface, a series of characteristic matching interpretation techniques with international advanced stage is creatively formed: (1)synergistic evaluation technique series for new area and frontier, (2)synthetic study technique series for subtle reservoir, (3)synthetic technique series for small fault block interpretation, (4)3D visualization interpretation technique series, (5)production seismology reservoir description technique series, (6)variable velocity mapping technique of subtle structures of buried overthrusts, (7)carbonate reservoir prediction technique.

Geophysical method research- An abundant achievements was obtained in “complex layout design technique”, “denoising technique of seismic data with low signal-to-noise ratio”, “static correction technique”, “high resolution data processing technique”, “VSP data processing, interpretation techniques”, “multi-wave multi component data processing technique”, “prestack migration processing technique”, “forward modeling technique”, “high density spatial sampling seismic data processing technique” and other aspects. The new methods and techniques of geophysical prospecting were continually provided for progress and innovation of prospecting technology.

Software system research and development for geophysical prospecting- The techniques of proprietary intellectual property rights, “GeoEast seismic data processing, interpretation integrated software system”, “KLSeis seismic acquisition engineering software system”, “GRISYS seismic data processing system” and “KLInversion reservoir monitoring and synthetic inversion system” etc. have been applied widely in oilfields and exploration areas both abroad and home.



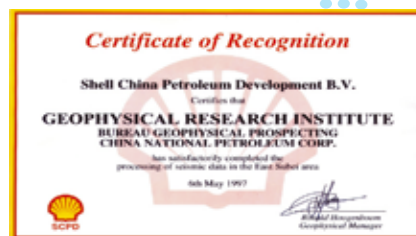
The Integration of processing and interpretation-

Integrated research and development of seismic data processing, data interpretation, synthetic geological study;

Ultra-large type parallel processor cluster with 14000 CPU, and 35 sets of processing and interpretation workstation assembly;

The advanced processing and interpretation software system.

Geophysical prospecting equipment research- The center has the independent research and development capability for electromechanical geophysical prospecting equipments such as seismic source, air gun, drilling rig, special kinds of carrying chassis etc., and large seismic instruments and additional instruments, forming the products of five main series, over twenty varieties.





Li Qingzhong

Academician, Chinese Academy of Engineering, famous geophysicist. He was the first to bring forward physical seismology. His work, Head for Exact Exploration Approach, opened the milepost of high-resolution surveys in China.



Qian Rongjun

Senior technologist. He took charge of the national highlight projects, Seismic Prospecting Technique in Large Desert of Low Signal-to-noise Ratio, Vector Seismic, Mountain Seismic. He formulated a systemic solution for giant gas fields such as Kela-2 etc. discovered in Kuche of Tarim basin.



Ling Yun

Senior technologist. His research area is mainly the seismic data processing and interpretation techniques, seismic prospecting and development techniques of stratigraphic and lithologic traps. His main achievements include: "Applied research of width azimuth in seismic prospecting", "Research of prestack relative retention amplitude, frequency, phase and wave processing", "Spherical spreading and absorption compensation in time frequency domain and spatial domain", "Surface consistent deconvolution of self-adapting vibrators", "Seismic analysis of reservoir evolution", "Processing method of time shift seismic prospecting etc.



Wang Weihua

Senior technologist. In view of the complex surface conditions in mountain fronts of China, he researched the stimulation and observation techniques of seismic waves, and brought forward the seismic corridor problem in mountain prospecting and its solution.



Zhan Shifan

Senior technologist. He proposed the depth migration method in Mountain of Flames and solved imaging problem for thrusting nappes. The Investigation method of surface layer in massive gravel area solved low relief structure problem. Furthermore, His virtual solution solved the tackling key problems of deep zone in Turpan-Hami Basin. As the principal of "multi-wave seismic prospecting technique objective", he formed and improved the passel multi-wave seismic data acquisition, processing and interpretation techniques.



Deng Zhiwen

Senior technologist. He has fulfilled the study of the seismic technique in large desert, 3D seismic technique in mountain, static correction and nonzero VSP imaging etc. and applications in the Western China for a long time. In the past few years, he principally involved in the study of reservoir geophysics in the Eastern China, and took on the research projects of 3D multi-component seismic, and 3D 3C VSP data acquisition and processing etc.



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