

OIL GEOPHYSICAL PROSPECTING

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ABSTRACTS

Numerical modeling using staggered-grid high-order finite-difference of elastic wave equation on arbitrary relief surface. Pei Zheng-lin. *OGP*, 2004, 39 (6): 629~634

There are mainly two issues when carrying out numerical modeling of elastic wave on arbitrary relief surface, the first is how to solve elastic wave equation; the second is how to handle free-boundary condition. First, started from the expression of Taylor's series, the paper deduced the expression of staggered-grid first spatial derivative having arbitrary even-order precision and relative computing formula of differential coefficients as well as solved equation of first hyperbolic staggered-grid stress-velocity elastic wave equation that the difference format has arbitrary even-order precision. Second, the free-boundary is handled by using combination of the zero-velocity method with the general ghost-image method and fourth-order difference format is used in free-boundary. The numerical modeling tests are carried out for smooth relief model and arbitrary relief model by using abovementioned methods. The results showed that the methods described by the paper are characteristics of good stability and high precision of modeling, which is suitable for modeling of elastic wavefield on arbitrary relief surface.

Key words: arbitrary relief surface, elastic wave equation, staggered-grid, high-order finite-difference
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Noise-elimination and compression of seismic data using balanced biorthogonal multi-wavelets transform. Wu Ai-di and Cao Si-yuan. *OGP*, 2004, 39 (6): 635~645

Through the real cases, the paper discussed the process using balanced biorthogonal multi-wavelets transform to implement noise-elimination and data compression of seismic data. The processes of noise-elimination are follows: ① using components of high-frequency and high-wavenumber to evaluate variance of random noise in multi-wavelets domain; ② variation of seismic data minus variance of noise is equal to variance of useful signal, then threshold is computed, using soft threshold value processing method for noise-elimination; ③ the noise-eliminated signals are resulted from

the inversion wavelet transform. The processes of data compression are follows: ① decomposing the seismic data into 4 layers by balanced biorthogonal wavelets BSA6/6, the decomposition is carried out only for low-frequency parts each time; ② rearranging each 2×2 sub-block so that the 4 coefficients that have same special positions are arranged together (original 16 sub-blocks now became 4 sub-blocks), that met the parent-child relationship required by SHIFT coding scheme; ③ embedded coding is carried out for the tree of each level, using improved wavelet zero-tree code scheme to compress seismic data. Experiment results showed that the method in the paper is superior to the noise-elimination and data compression methods by single wavelet.

Key words: balanced multi-wavelets, multi-scale function, noise-elimination, data compression, signal-to-noise ratio

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Split-step Fourier prestack depth migration by velocity partition. Zhang Shu-lun, Wang Chang-long, Zhao Jing-xia and Sun Pei-yong. *OGP*, 2004, 39 (6): 641~644

The paper presented split-step Fourier prestack depth migration method using velocity structure to partition the velocity field. The theoretical basis of Split-Step Fourier (SSF) method is disturbance item, when the velocity contract is large, the errors of disturbance item become larger in one step length of wavefield continuation. Therefore, when lateral velocity has rapid variation, the velocity partition is implemented according to velocity structure and using different reference velocities in each velocity zone, which can greatly reduce the contracts between the reference velocities and real velocities and then increase the imaging precision of split-step method; meanwhile, it can greatly reduce the numbers of used reference velocities and reduce the computational efforts to minimum. The implemented steps are follows: ① the max and min velocities of a particular layer are computed within each continuation step first, then an adequate boundary velocity is defined between both velocities; ② taken the boundary velocity as boundary, the velocity zone is divided into several high-velocity sub-zones

and low-velocity sub-zones and the velocity continuity between different sub-zones is unnecessary; ③ using different reference velocities in different velocity sub-zones to implement wavefield continuation by SSF method, i. e. phase-shift is implemented first in the frequency — wavenumber domain, then split-step method is realized point by point back to the frequency — space domain; ④ merging the different wavefields resulted from partitioned continuation according to relevant grid points and carrying out the adequate smooth processing when different wavefields are merged; ⑤ repeat above-mentioned steps until finishing continuation and mergence of all velocity partitions. Theoretical analysis, poststack depth migration of simple models and prestack depth migration of Marmousi model showed that the method is feasibility.

Key words: split-step Fourier method, velocity partition, disturbance method, wavefield continuation
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Generalized non-linear P wave and S wave velocity inversion of prestack AVA. Meng Xian-jun, Jiang Xiu-di, Huang Han-dong and Wei Xiu-cheng. *OGP*, 2004, 39(6): 645~650

Using prestack AVA seismic data for inversion of underground P wave and S wave velocities can provide abundant elastic parameters for interpretation of stratigraphic lithology, physical nature of reservoir and oil-bearing characters. Based on approximate formula presented by Mr. Aki and Richards, the paper transforms the least square issues into finding the solution of large-scale sparse matrix, directly makes the inversion of P wave and S wave velocities; deduces generalized non-linear matrix inversion equations based on built inversional object function; adding covariance matrix of noises and covariance of model can improve the stability of prestack inversion; joint constraints by labeling of AVA synthetic records, evaluation of AVA inversion wavelet and logging and structural beds information can effectively reduce the issue of multiple solutions of inversion. Theoretical models test and real data processing showed that the method has good processed results.

Key words: prestack AVA inversion, data processing, P and S waves velocities, constrained inversion, gradient matrix, Hessian matrix

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Coherent-enhancing anisotropic diffusion filtering

technique. Sun Xi-ping, Du Shi-tong and Tang Lei. *OGP*, 2004, 39(6): 651~655, 665

Coherent-enhancing anisotropic diffusion filtering is an imaging restoring technique in scale space. The paper discussed the general filtering structure of coherent-enhancing anisotropic diffusion, examined the advantages and disadvantages using finite-difference method for solving the explicit evolution equation based on the conception of diffusion tensors presented by Mr. Weichert et al and pointed out the steps of anisotropic diffusion filtering characterized by optimum rotation invariability are follows: ① using optimum derivative filtering of template to compute structural tensors; ② composing diffusion tensors by structural tensors; ③ using optimum filtering to compute the right item of evolution equation; ④ using optimum derivative filtering to compute the left item of evolution equation; ⑤ implementing following computation by explicit mode. In a process of study, the character of preserving edges is preserved by improvement of algorithm. Using the technique for seismic data processing, on the one hand, it can eliminate noise, increase signal-to-noise ratio and improve data quality; and on the other hand, it can also enhance continuity of reflection events, which is useful for interpretation of low S/N ratio data. Applied real cases showed that the data quality has been greatly improved after filtering processing, highlighting contacting relation between layers and enhancing imaging ability of internal structures of sequence body by seismic data.

Key words: diffusion filtering, image restoration, edge detection, preserving edge nature, directional flattening

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RG — statics of equivalent LVZ. Lin Bo-xiang. *OGP*, 2004, 39(6): 656~660

The paper discussed the concepts of equivalent low-velocity zone (LVZ), floating datum and fixed datum related to static corrections in data processing in complex subsurface conditions; expounded that the RG values in common-used two-step static corrections method represents the statics of relatively fixed datum in equivalent LVZ; the zero point of t_0 value corresponds to top interface of equivalent LVZ after application of the high-frequency components of statics to seismic data; the influence of LVZ velocity and lateral change of thickness on time-to-depth inversion was described

by theoretical records, the stack velocities also change when the lateral structures of LVZ have larger variation, so the influence of LVZ on stack velocities should be considered in time-to-depth inversion.

Key words: static corrections, RG value, equivalent LVZ, fixed datum, floating datum, low-frequency components of statics, high-frequency components of statics

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Dual optimization of seismic attributes based on Grey association analysis and K-L transform. Zhao Jia-fan and Chen Xiao-hong. *OGP*, 2004, 39(6): 661~665

Combination of Grey association analysis with K-L transform can realize the dual optimization of attributes. Using Grey association analysis realized the sensibility analysis of seismic attributes and built up Grey association between the reservoir parameters and attributes. On that basis, mapping of high-dimension attributes onto low-dimension attributes in attributes space is carried out by K-L transform and eliminated the correlation among the attributes so that can effectively solve the optimized issue of attributes combination. Using BP neural network for prediction of targets showed that the dual optimization method of seismic attributes combined Grey association analysis with K-L transform can fully display individual advantages of each method, which is a great help to solve the issues of attributes analysis, association and combination optimization, then improves the operation speed and precision of seismic reservoir prediction.

Key words: reservoir prediction, Grey association analysis, K-L transform, neural network, attributes combination, attributes optimization

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Identification of barrier bar sand body in Jiyang Depression and its geophysical feature. Wang Jin-duo. *OGP*, 2004, 39(6): 666~671

Because of higher energy of lake wave and running water medium in barrier-bar-developed zone and eroded clastic sediments for a long period, the barrier bar sand body has excellent oil/gas accumulation characters, which is one of important tar-

gets of reservoir exploration but difficult to be identified. The rhythm feature of logging curves provided direct basis for identification of sand body in different developed parts, the composition of rhythm feature also further reflected the changes of lakeshore and whole process that the sand body generated, developed and died out. After correlation of the structural feature of current barrier bar sand body and using the characters of logging curves of barrier bar sand body, the paper first presented that the sand body in Guangli-Bamianhe region is palaeo-barrier bar sand body and firstly using time-frequency analysis technique and sedimentary facies analysis technique for identification of palaeo-barrier bar sand body, that not only verified the existence of barrier bar sand body in the region, but also found barrier bar sand body in Chexi depression. The Guangli-Bamianhe oilfield belongs a hundred million ton oilfield and the reservoir having palaeo-barrier bar sand body type, which has active meaning for expanding types of oil/gas exploration in Jiyang Depression.

Key words: barrier bar, rhythm, logging facies, time-frequency analysis, seismic facies

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Seismic analysis of reservoir evolution. Ling Yun Research Group. *OGP*, 2004, 39(6): 672~678

As far as continental thin reservoir is concerned, the current seismic resolution is difficult to meet the needs of oilfield development. Obviously, only breaking through 1/4 wavelength limit in the common seismic exploration theory, it has possibility for using seismic exploration methods to study the issues in exploration and development of China continental thin reservoirs. In view of the issue and on the basis of hi-fi processing studied by the predecessors, the author presented the processing ideas of relatively preserving amplitude, frequency, phase and waveform under the condition of eliminating near-surface influence and the labeling by reference marker as well as a set of technical ideas of continuous detection of seismic attributes and dynamic interpretation based on reference marker. The author considered that the spatial change in thin-reservoir information less than 1/4 wavelength could be identified by interpretation of spatial difference in dynamic seismic attributes. The successful application of the technical ideas to many oilfields in China showed that using the set of technical ideas of identifying thin reservoir can gain sedimentary evolution information of thin

reservoir less than $1/4$ wavelength, and further form a model of "seismic analysis of reservoir evolution". The difference between seismic analysis of reservoir evolution and lithological seismic exploration is further discussed in the paper and difference and link with sequence-stratigraphy are also discussed. On that basis, the paper systematically discussed the applied mechanism of seismic analysis of reservoir evolution and practical applied results.

Key words: sedimentary evolution seismic exploration, lithologic seismic exploration, sequence — stratigraphy

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Wavefield characters of 2-D elastic random medium. Xi Xian and Yao Yao. 2004, 39(6): 679~685

Through the staggered-grid finite-difference forward modeling of wave equation, the paper modeled the propagation of seismic wave in 2-D elastic random medium and self-excited and self-received time-records; comparison of acoustic wave with elastic wave is made in layered random medium model, which showed that both have big difference. In order to study the wavefield characters in 2-D elastic random medium model, we divided the theoretical records into three different time segments and computed three statistical characteristic values of section separately in three different time segments; laterally central frequency, vertically central frequency and relative value of wavefield energy. Then, corresponding to each elastic random medium model, 9 different wavefield-characterized values are obtained by computation. Finally, through studying the changed characters corresponding to characteristic values of wavefield when medium models are changed; the conclusion that closely related the model characters (self-correlation length and roughness of random medium etc.) to wavefield characters (disturbed frequency and energy of recorded section etc.); the statistic characteristic values of wavefield strongly rely on statistic characters of medium, such as correlation length and roughness etc.; the seismic records corresponding to random medium models are characterized by complex wavefield such as scattered wave and seismic wave tail.

Key words: random medium model, elastic wavefield modeling, wavefield character, statistic characteristic value

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Smear-eliminated technique of image used for fault detection. Lu Wen-kai, Zhang Shan-wen and Xiao Huan-qin. OGP, 2004, 39(6): 686~689, 696

3D post-migration seismic data volume provided a great number of information for seismic interpretation. Because of influence of aperture of migration operator, the image of 3-D seismic data volume in space is smeared after migration, which is unfavorable for detecting the faults. Therefore, the paper presented using smear-eliminated technique of image to enhance fault information of 3D seismic data volume. The nature of the method is to take observed image as convolution of true image with expansion function at a point, and the smear-eliminated technique of image is to eliminate the influence of expansion function at the point by multi-dimension deconvolution, then adding coherent analysis resulted in high-resolution image. The method is of benefit for fault detection.

Key words: fault detection, smear-eliminated technique of image, coherent analysis

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Refraction ray-tracing in complex medium. Xu Tao, Xu Guo-ming, Gao Er-gen and Jiang Xian-yi. OGP, 2004, 39(6): 690~693

Starting from 2-D layered medium model, the paper described the theory of iterative refraction ray-tracing segment by segment; as the primary ray-paths connecting shot-points and receiver points met Fermat's principle, the ray-paths connecting three arbitrary points also met the Fermat's principle. Accordingly, the first-order modified formula for transmitted intermediate points and refracted points is derived and whole ray-path can be computed for refracted ray iteratively segment by segment. The first-order explicit modified increment formula at refracted points of arbitrary interface is derived and the principle is popularized to the 2-D blocky medium model, which is used to solve refraction ray-tracing in complex medium that avoids solve the high-order, multivariate equations and is characteristic of fast computational speed and suitable for arbitrary interface. The paper also pointed out that the reasons having bigger difficulties in blocky medium than in layered medium when using iterative ray-tracing segment by segment are in increasing and deleting the ray-path points. The real case showed that the

method in the paper is an effective refraction ray-tracing method.

Key words: blocky model, ray-tracing, refraction, iteration segment by segment

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Study on characteristics of imaging frequency variation in cross-hole seismic reflection. Wang Yan-guang and Wang Cheng-li. *OGP*, 2004, 39(6): 694~696

Cross-hole seismic sections have some speciality in comparison with ordinary surface seismic sections, among which the low frequency in shallow parts of section is one of its basic characters. The paper studied the issue of low frequency in shallow parts of cross-hole seismic reflection sections using imaging principle and deduced frequency variation factor. The studied results showed that the phenomenon of low frequency in shallow parts of observed well mainly resulted from "stretching" in imaging processing. The rule of variation is that the frequency gradually changed toward the low frequency direction from deep parts to shallow parts and from middle parts of two wells to both sides of two wells. These low-frequency components don't reflect the true frequency character of reflection in that parts of layers, to which it must pay more attention in a process of data inversion and interpretation, otherwise, it can lead to mistaken interpretation results.

Key words: cross-hole seismology, reflection, low-frequency, frequency variation factor

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3D AVO analysis in Daqing area. Fu Lei, Liu Cai, Li Qin-xue, Wang Jian-min, Liu Zhen-biao, Cui Feng-lin and Kong Xiang-bo. *OGP*, 2004, 39(6): 697~700, 710

The offsets and folds increased along with the constant improvement of seismic field acquisition methods and the gradual increase of field-acquired channels, and S/N ratio of seismic data has been greatly improved, especially along with the gradual improvement of AVO techniques, it is necessary to renew the knowledge of the AVO characters of seismic data in Daqing area in order to better identify the lithology and detect the oil/gas anomaly. The area of the AVO study is selected in 3D work area of Songzhan Sheng-81 well, the obvious AVO anomaly is obtained from the AVO processing and

analysis for inline 142 of Sheng-81 well and AVO forward modeling is carried out by using logging trace associated with Sheng-81 well, the results proved that there exists AVO anomaly in Sheng-81 well. The deep volcanite is discovered by 3D AVO techniques and the channel position of volcanic eruption is preliminarily determined.

Key words: 3D AVO analysis, AVO foreword modeling, AVO anomaly, volcanics reservoir, volcanic channel

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Interpretation technique of Lower Cretaceous Quan Formation forth segment reservoir in Jilin Oilfield. Yang Guang-da, Qin Wen-ming, Miao Zhi and Guo Hong-wei. *OGP*, 2004, 39(6): 701~705

Seismic attributes are not only used for structure interpretation and reservoir interpretation, but also used for interpretation of sedimentary environment. The paper used the layer-flattened amplitude slices to interpret the reservoir and sedimentary environment. The Quan Formation forth segment showed the wave group consisted from 4 phases on seismic reflected sections. It is discovered from correlation with drilling and logging data that each phase has definite geologic significance. Some geologic scenarios are clearly showed after layer-flattened processing such as channel distribution, multi-period stack fan sedimentary body, overlap of upper layer and lower layer that provided a reliable basis for interpretation of reservoir and sedimentary environment.

Key words: layer flattening, horizontal slice, reservoir prediction, stratigraphy, fan sedimentary body

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Application of logging-restrained seismic inversion to study complex fault block in He-4 well block. Zhao Qing-guo, Zhao Hua and Zhu Ying-ke. *OGP*, 2004, 39(6): 706~710

He-4 well block situates in central ridge zone of Dongying sag, because of complex rift system in that well block, poor seismic data quality and rapid lateral variation of reservoir, the distribution of the sand body of middle and lower reservoir of S₃ Formation is unclear, which restricted the exploration and development of the new bed set. The logging-restrained seismic inversion technique is applied in the area, taking fine interpretation of layers and

faults, building up wave-impedance model conformed with geologic rule of complex rift zone, the wave-impedance data volume with high-resolution is finally obtained by inversion. Using wave-impedance inversion data volume to implement reservoir prediction, distributed rule of sand body and sedimentary rule of reservoir in complex rift zone are revealed. Total 30 sand bodies have been described by using the method, 15 favorable drilling targets have been presented, provided a solid basis for developing middle and lower reservoir of S₃ Formation in down-dropped block of He-13 fault in that well block.

Key words: logging-restrained seismic inversion, wave impedance, complex fault block, geologic model, reservoir prediction

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Using array sweeping to suppress harmonic distortion. **Cao Wu-xiang.** *OGP*, 2004, 39(6): 711~715

In a process of acquisition by vibroseis, because of different surface conditions, the non-linear nature of mechanic driven unit and the coupling issue between vibrator and ground resulted in signals of harmonic interference in different order that are multiple relation with the signal of basic wave in frequency, which are mixed in raw records. The common methods for suppression of harmonic interference is to carry out phase-changed sweeping, using the phases different to each sub-sweeping to suppress harmonic interference by correlation summation. The paper introduced a new method for suppression of harmonic interference, that is array sweeping method. The harmonic interference reduced with decrease of the width of sweeping frequency band, when the sweeping frequency band reached an octave, the harmonic interference disappeared. The basic idea using array sweeping to suppress harmonic interference is to reasonably design each sub-sweeping frequency band that can reach the goal of elimination of harmonic interference.

Key words: vibroseis, array sweeping, harmonic distortion, width of sweeping frequency band, octave

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Imaging by electromagnetic Reflection function continuation for MT. **Hou De-jin, Zhang Ye-sheng and Wang Jia-ying.** *OGP*, 2004, 39(6): 716~719

The paper presented a new imaging method of

wave-equation continuation for MT — imaging by electromagnetic reflection function continuation for MT characterized by simple practice, few acquired conditions and high-precious imaging, simply called as IRC. First the paper introduce the IRC theory in 1-D medium, deduced electromagnetic reflection function of MT that represented by ratio between upgoing and downgoing electromagnetic waves; then the operational feature and steps of imaging method of reflection function continuation for MT are given; finally using the method and pseudo-seismic interpretation method to compute the model and real data near borehole in order to expound the feasibility and practice of the method. The method not only makes interface correct imaging, but also computes such parameters as true impedance etc, not affected by upper interfaces.

Key words: pseudo-seismic interpretation, electromagnetic wave equation, electromagnetic reflection function, continuation function

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Static correction method of planer cluster. **Xu Jian-rong.** *OGP*, 2004, 39(6): 720~723

The corrections of static effect in MT method is always the issue that widely following with interest by the people engaged in electric exploration at home and abroad, who presented a variety of solution methods, among which the parallel curve shift correction method is currently mainly-used method. The apparent resistivity between sections may produce systematic errors after correction and unequal apparent resistivity values may be produced at intersect of two lines when using the parallel curve shift correction method for areal exploration; on the other hand, the sudden variations in curve values resulted from real geologic structural changes may be viewed as static shift and removed by using the method, which resulted in loss of useful information. For this reason, the paper presented static correction method of planer cluster that implements Hanning filtering first on plane, then the cluster analysis is implemented for apparent resistivity curves at each surveying point in exploration area, that can automatically reach the goal of the corrections in separate zones of structural units. The comparison of the applied cases by using the method with seismic sections in same segments showed that both of them are comparable and that means the method is effectiveness.

Key words: MT, static effect, cluster analysis

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Rift system of Dongpu sag and its meaning. Wang Jing-yun, Song Hui-Li, Wang Zheng-bin, Liu Shu and Jin Zhen-hua. *OGP*, 2004, 39(6): 724~729

The faults is common geologic structural phenomenon in faulted basin, therefore, studying the rule of faults is of great importance. The people usually call a group of faults that have same extension direction or similar extension direction on the plane as a "fault system", which is static description of faults on the plane and highlights the strike of faults on the plane; The paper calls an assemblage of faults that have same cause of formation, same age, different scales, trends and strikes as a rift system, one rift system can include several fault systems. The rift system is 4-D description and analysis that include stereo nature and timeliness of faults. Different from the rift system of tectonics presented by Mr. Zhang Wen-you, the rift system expounded in the paper is related to sag, the analysis of this rift system is helpful to study the faults and appreciate the relation with oil/gas reservoir.

Key words: fault, fault system, rift system, local structure, reservoir

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Using frequency attribute to identify and divide multi-period time-frequency sequences of continental basin: case of Lower Cretaceous Qingshankou Formation — Yaojia Formation in northwest Qian area of Songliao Basin. Xia Zhu, Zhang Zhen-sheng, Sun Chang-hong, Chen Geng-yi and Chen Yi. *OGP*, 2004, 39(6): 730~738

Lower Cretaceous Qingshankou Formation — Yaojia Formation in northwest Qian area of Songliao Basin is important targets of seismic exploration and development in Jilin Oilfield, having complex thin sandstone/mudstone-interbedded structure of lake basin. Former-used common interpretation methods for identifying the thin reservoirs based on common seismic data have ability falling short of our wishes. We begun to explore a set of the methods for identifying and dividing thin sandstone/mudstone interbedded multi-period time-

frequency sequences after finishing 3-D high-resolution seismic exploration in that area and using frequency attribute and directional change of frequency in time domain of 3-D time-frequency seismic data volume to identify and divide the time-frequency sequences in different periods. The studied results showed that there exists the good corresponding relation between stratigraphic sequence and time-frequency sequence, that means, the seismic response of stratigraphic sequence has directivity in frequency, the frequency of different type's sequence has different directional character, the distributed feature of frequency in time-frequency analysis sections conforms to sedimentary regularity of formations. It considered in view of the above that the method has good application prospect in the aspect of analyzing thin sandstone/mudstone interbedded sequence of continental facies.

Key words: time-frequency analysis, time-frequency sequence, seismic sequence, sedimentary cycle

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Present conditions of subtle traps exploration and analyses of adapted measures. Wang Huan-di, Niu Bin-hua, Ren Dun-zhan, Wen Shu-liang and Yang Jian-Li. *OGP*, 2004, 39(6): 739~744

Subtle traps have different definition, but more consistent knowledge now is that there is more difficulty in identification and description of trap patterns in a condition of present exploration methods and technical competence. At present, it includes sand/gravel body, vulcanite body, deep buried-hill, anticline with low amplitude and fractured reservoir etc. Through analyzing the present conditions of subtle traps exploration and principal difficulties in China, the paper presented the adapted measures of subtle traps exploration, they are: renewing exploration ideals, optimizing exploration methods, developing study and appreciation in every aspects, multidisciplinary joint exploration and bold application of new theories and new techniques etc. The authors considered that repeated knowledge and constantly bringing forth new ideas into techniques are effective way that subtle traps exploration continuously achieves breakthrough.

Key words: subtle trap, exploration strategy
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