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地震纹理属性在 JJD工区断层识别中的应用

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摘 要: 纹理分析是图像处理中的一种常用技术, 通过构建地震纹理基元和灰度共生矩阵, 可以将此项技术推广到地球物理领域, 并可在断层识别, 边缘检测和沉积相划分等方面得到应用。这里通过算法研究和程序开发, 结合 JJD 工区应用实例, 得到了有一定理论意义和研究价值的结论: ①基于灰度共生矩阵提取的纹理属性, 是一种很好的凸显断层和裂缝信息的地震属性; ②可以根据实际地质问题, 提取不同方向的纹理属性, 并用 RGB 技术进行多属性的融合; ③地震纹理基元的窗大小取 9×9×9为好; ④要根据具体情况选取合理的灰度级别, 对于常规三维地震数据, 灰度级别取 16或 32比较理想。

关键词: 纹理; 体素; 灰度共生矩阵; RGB技术; 断层
中图分类号: P 631.4 文献标识码: A

0 前言

纹理(Texture)是按一定规则进行排列所形成的重复模式, 或以一定的形式变化而产生的图案[1~4]。在自然界中, 许多植物、动物、矿物, 都有其独特的纹理特征。利用它, 人们可以方便地识别或区分事物。在图像处理领域, 利用纹理分析, 可以在图像分割, 模式识别, 形状分析, 纹理合成和图像压缩等方面得到广泛应用。

地层由于受构造运动的影响, 也会产生断层、裂缝等地质现象, 从而留下地质年代变迁的印记。这些痕迹, 从图形学上来说, 可以认为它们就是纹理, 可以借助于图像处理的方法、手段, 来凸显其内部特征, 从而有效地识别断层或裂缝, 为找油、找气提供更好的依据[5~7]。

在过去的勘探历程中, 地球物理工作者通过不断努力, 已经用三维地震勘探技术较好地查明落差和断距较大的断层。而对于落差和断距较小的断层识别, 无论在理论上还是在实践上, 都有很大困难。相干体算法也是从 Bahorich和 Farmer[8]的第一代的互相关算法, 发展到 Marfurt[9,10]的第二代多道相似算法和第三代特征值相干算法。近几年来, 以 Gao Dengliang[11~13]为首的研究小组, 利用纹理属性进行断层识别研究, 并取得了一系列成果。作者在本文中, 借鉴其纹理分析的相关方法原理, 研究了三维纹理体的提取算法, 获得了纹理能量、熵、对比度, 以及相关性等纹理属性体, 讨论了纹理基元大小选择, 灰度级确定, RGB数据融合等应用要素, 并在 JJD实际工区中取得了较好的应用效果。

1 基于灰度共生矩阵的纹理分析方法

灰度共生矩阵是一种用来分析图像纹理特征的重要方法, 它最早由 Haralick于 1973提出。通过计算图像中一定距离和一定方向的二个像素之间的灰度相关性, 可对图像的所有像素进行统计, 从而反映出图像在方向、相邻间隔、变化幅度及快慢上的综合信息[14,15]。对于一个已经用灰度来描

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述的图像 G 来说，沿着某一方向统计其距离为 δ 的任意二个像素点，满足一定条件出现的概率 $p(i,j)$：

$$p(i,j)=\sum\{g(x,y)=i,\ g(x+\Delta x,\ y+\Delta y)=j;\ x=0,1,\cdots,N_x-1;\ y=0,1,\cdots,N_y-1\} \quad (1)$$

式中　$i,j=0,1,2,\cdots,L-1$，L 为图像的灰度级数；x、y 是图像中的像素坐标；$g(x,y)$ 是 (x,y) 处的灰度值；$\delta=\sqrt{\Delta x^2+\Delta y^2}$；$N_x$、$N_y$ 分别为图像的行列数。

在 p 值经归一化处理后，可写成灰度共生矩阵，形式见式 (2)。

$$\boldsymbol{R}=\begin{bmatrix} p_{0,0} & p_{0,1} & \cdots & p_{0,L-1} \\ p_{1,0} & p_{1,1} & \cdots & p_{1,L-1} \\ \vdots & \vdots & \vdots & \vdots \\ p_{i,0} & p_{i,1} & \cdots & p_{i,L-1} \\ \vdots & \vdots & \ddots & \vdots \\ p_{L-1,0} & p_{L-1,1} & \cdots & p_{L-1,L-1} \end{bmatrix} \quad (2)$$

容易推知，$\boldsymbol{R}$ 是一对称阵，位置偏移 δ 由 x 方向和 y 方向的二个量组成。一般来说，δ 较小则反应图像的整体纹理分布，而较大的 δ 则反应小区域的细微变化。

用灰度共生矩阵可提取多种特征值，最常用的是以下四个特征：

(1) 角二阶矩或能量。它是纹理灰度变化均一的度量，反映了灰度分布均匀程度和纹理粗细度。

$$Energy=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}p_{i,j}^2 \quad (3)$$

(2) 熵。它可以度量纹理的随机性。当共生矩阵中所有值均相等时，它取得最大值；相反，如果共生矩阵中的值非常不均匀时，其值较小。

$$Entropy=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}p_{i,j}\log p_{i,j} \quad (4)$$

(3) 对比度。它是灰度共生矩阵主对角线附近的惯性矩，它度量矩阵值的分布和局部变化，可反映清晰度和纹理的沟纹深浅。

$$Contrast=\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}(i-j)^2 p_{i,j} \quad (5)$$

(4) 相关性。它度量空间灰度共生矩阵元素在行或列方向上的相似程度。因此，相关值大小反映了局部灰度相关性。

$$Correlation=\left\{\sum_{i=0}^{L-1}\sum_{j=0}^{L-1}(i+1)(1+j)p_{i,j}-\mu_x\mu_y\right\}/(\sigma_x\sigma_y) \quad (6)$$

其中

$$\mu_x=\sum_{i=0}^{L-1}(i+1)\sum_{j=0}^{L-1}p_{i,j};$$

$$\sigma_x=\sum_{i=0}^{L-1}(i+1-\mu_x)^2\sum_{j=0}^{L-1}p_{i,j};$$

$$\mu_y=\sum_{j=0}^{L-1}(j+1)\sum_{i=0}^{L-1}p_{i,j};$$

$$\sigma_y=\sum_{j=0}^{L-1}(j+1-\mu_y)^2\sum_{i=0}^{L-1}p_{i,j}$$

2　三维地震纹理体的提取原理

2.1　纹理基元的引入

地震数据体的振幅用灰度来表示，并按一定的窗去截取数据，可构建地震纹理基元 (Texture element)[8]。图 1分别展示了以体、剖面和道表示的纹理基元 (纹理元)。

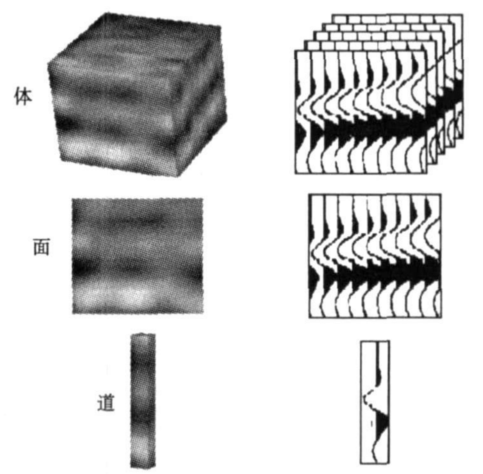


图 1　地震纹理元示意图

Fig. 1　The sketch diagram of seismic texture element

2.2　地震资料灰度共生矩阵的构建

地震资料灰度共生矩阵可在地震纹理元基础上构建，它反映了地震纹理体在方向、间隔、变化幅度方面的综合信息。对于图 1所示的纹理基元体，其灰度共生矩阵的矩阵元素值可通过下式来计算，即：

$$p(i,j,\alpha,\beta)=\sum\{(g(x_1,y_1,z_1)=i,\ g(x_2,y_2,z_2)=j)\ i,j=0,1,2,\cdots,L-1\} \quad (7)$$

式中　$g(x,y,z)$ 为纹理基元体中 (x,y,z) 点的灰度值；(x_1,y_1,z_1) 和 (x_2,y_2,z_2) 表示距离为 δ 的二个像素点；$\sum$ 表示纹理体中沿着某一方向距离为 δ 的任意二个像素点满足以上条件的概率统

计; α、β表示方向(见图 2)。特殊地, α = 90°, β = 0°对应 X 轴方向; α = 0°, β = 0°对应 Y 轴方向; β = 90°对应 Z 轴方向; L 表示灰度级数。

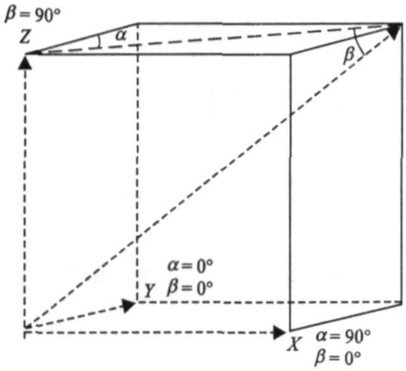


图 2 纹理基元体的不同方向

Fig. 2 The different directions of seismic texture element volume

3 实际资料应用及分析

选取胜利油田 JJD工区作为应用实例, 该区域断裂比较发育, 断层和裂缝对油气储集和疏导起主要的作用, 因此有效地识别断层和裂缝具有重要的研究价值。在计算时, 采用滑动纹理窗, 提取的属性包括纹理能量、对比、熵和纹理相关性等四种属性。此外, 还讨论了不同的计算方向, 时窗大小和灰度级别等应用要素问题。

3.1 不同纹理属性的对比分析

图 3(a)为某工区一沿层振幅切片, 为了检测断层, 用纹理属性来进行分析。通过试验, 采用 16 级灰度级别和 9×9×9的三维滑动窗提取纹理体属性, 然后抽取沿层切片进行对比分析。这里提取了纹理能量属性(见图 3(b)), 纹理对比度属性(见图 3(c)), 纹理熵属性(见图 3(d))和纹理相关性属性(见图 3(e))。对比图 3中四种纹理属性我们发现, 以上四种属性基本上都能较好地识别南部大的断层, 中部多条断层层次感也比原始切片要好, 纹理对比度和相关属性还较好地指示了北部的向斜构造。

3.2 计算方向对属性结果的影响

下面我们讨论纹理的方向性。图 4(见下页)给出了在三个不同方向上提取的纹理对比度属性, 最后用 RGB融合技术对三个方向属性进行融合。从图 4中可以发现, 不同方向的属性反应的断层是不一样的, 其中 x 方向(横测线方向)较好地反映了东西向的断层; 在 y 方向(主测线方向)上, 从图 4中还很好地展示出一古河道来, 这对油气储集的认识有重要意义; 在 z方向主要反映深度方向信

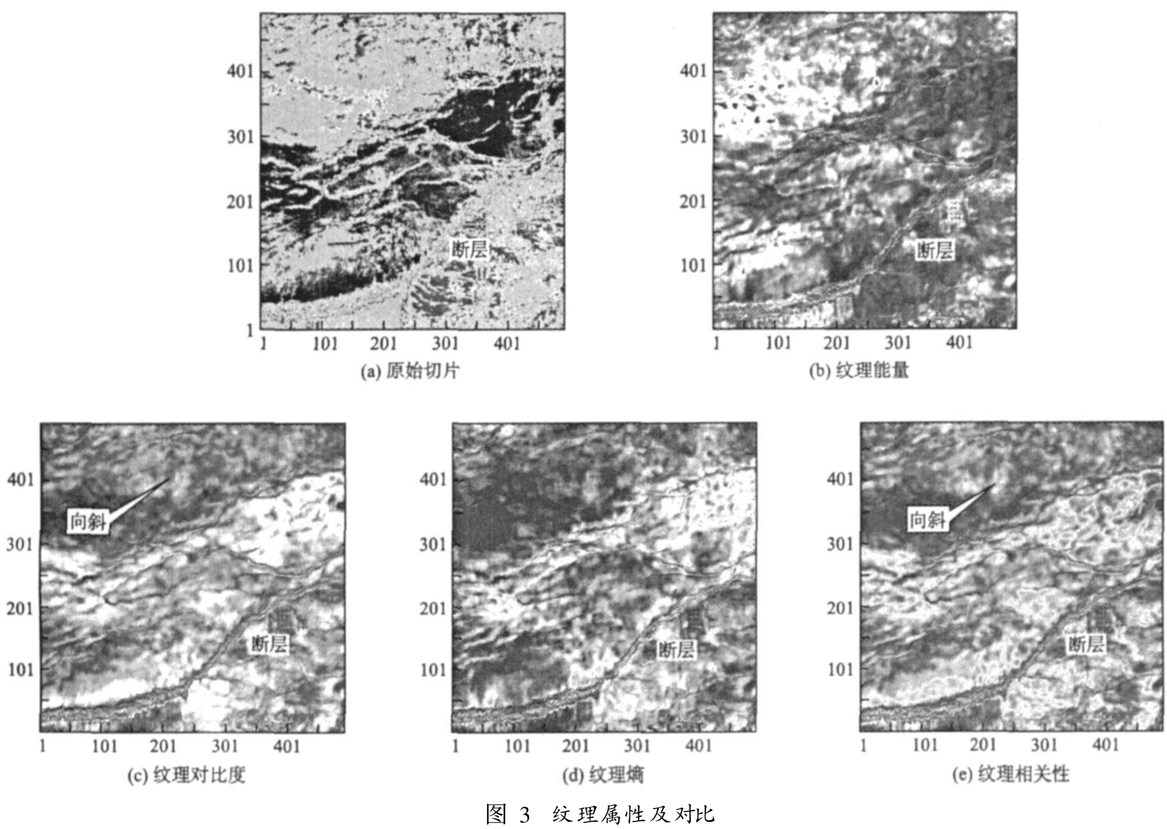


图 3 纹理属性及对比

Fig. 3 Texture attributes and comparison

息，较其它二个方向，此方向提取的属性，断层信息相对要清楚一点。我们还可用数据融合 RGB 技术，综合三个方向的属性，得到富有层次感、清晰的断层信息。

3.3 窗口大小对属性结果的影响

纹理计算肯定要涉及到窗口问题，这里以纹理相关性 z 方向属性为例进行说明。对比图 5 纹理相关性属性，我们可以发现：图 5(a) 虽然整体信息比较丰富，但背景噪音相当严重，图像模糊；图 5(b) 相对好一些，但局部噪音也比较严重；而图 5(c) 最好，背景噪音少，断层清晰。由此可见，窗口大小对纹理属性影响还是很大的，小窗口背景噪音比较严重，大的窗口则图像清晰，当然太大窗，也会带来信息被平滑掉的问题。通过对比，我们认为 9×9×9 体窗口比较理想。

3.4 灰度级别对属性结果的影响

在纹理属性提取时，除了要注意窗口大小的选择，还要注意灰度级别的选择。图 6(见下页) 以纹

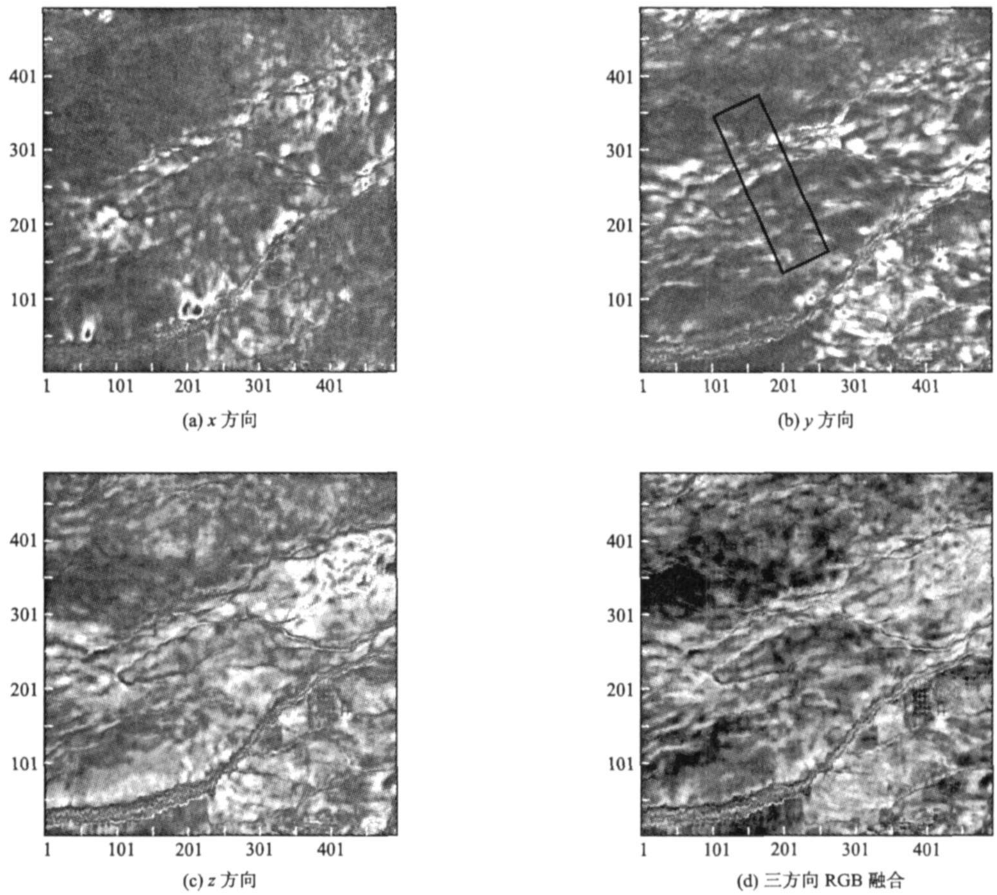


图 4 不同方向的纹理属性对比

Fig. 4 Texture attributes comparison of different directions

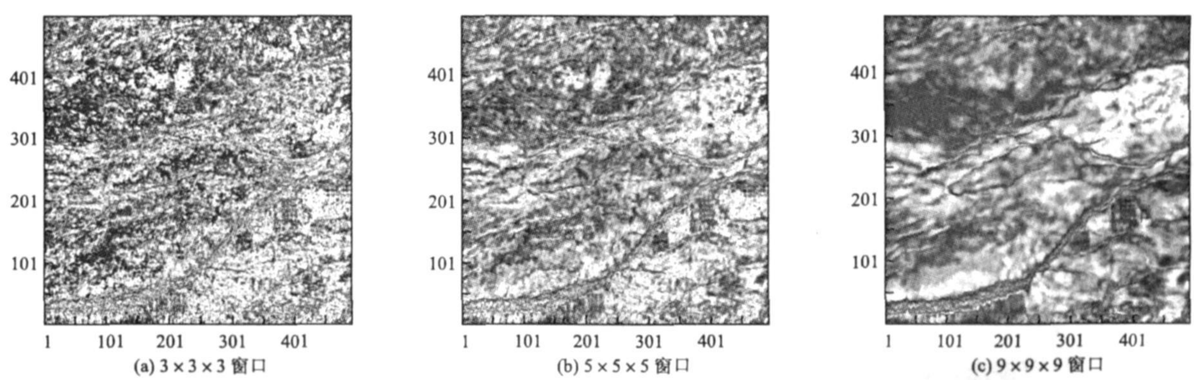
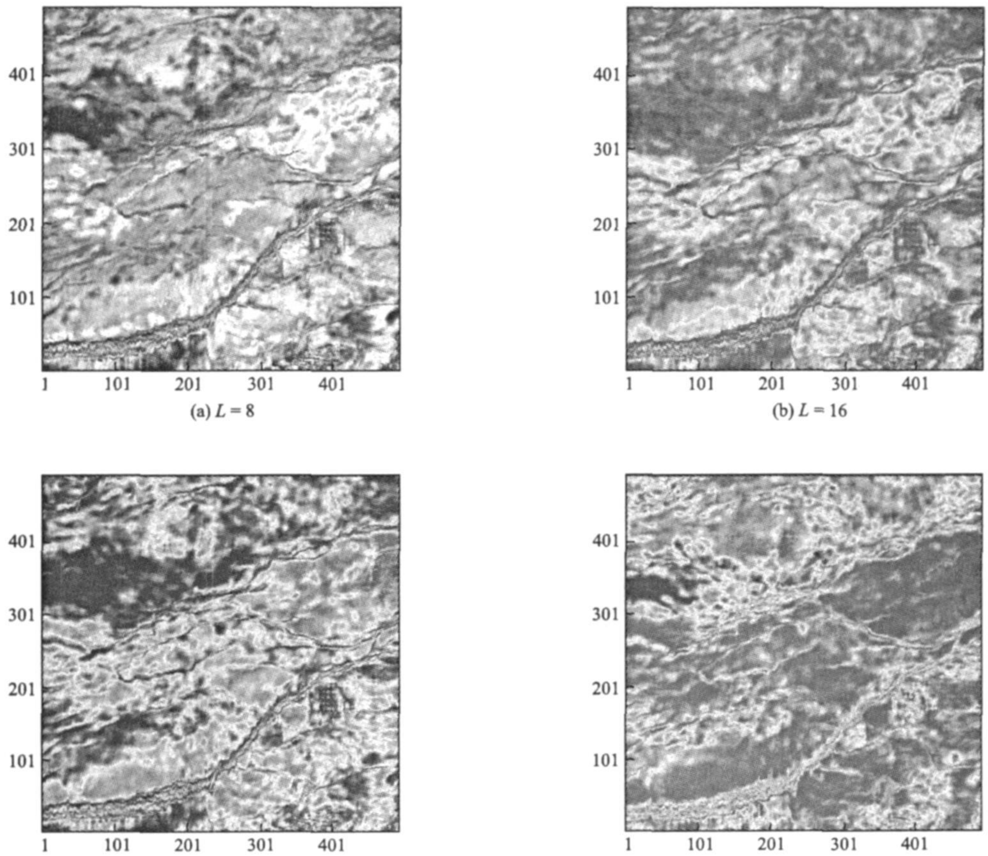


图 5 窗口大小对纹理属性的影响对比

Fig. 5 Texture attributes comparison with different windows



(a) $L=8$ (b) $L=16$ (c) $L=32$ (d) $L=64$

图 6 灰度级别对纹理属性的影响对比

Fig 6 Texture attributes comparison with different gray levels

理相关性 z方向属性为例,给出了同一窗口大小,不同灰度级别的属性图对比。从图 6中可以看出,并不是灰度级别越大越好,用较大的灰度级别,其内部结构的差异性并不能拉大(见图 6(d))。此外,灰度级别越大,计算速度会越慢。对于本区数据,取灰度级为 16或 32,效果较好。

4 结论

通过理论分析和实际应用,得到以下认识或结论:

(1)基于灰度共生矩阵提取的纹理属性,是一种很好的凸显断层和裂缝信息的地震属性。

(2)纹理属性提取涉及到方向问题,不同的方向反映的信息不同,可以根据地质需要提取某方向的信息,也可用 RGB技术来综合各个方向的信息。

(3)由于纹理属性是体属性提取,与窗口大小有密切关系,要根据不同的情况选取合适的窗,否则容易模糊信息,甚至产生假象。在一般情况下,窗口大小取 $9\times9\times9$为好。

(4)灰度级别对纹理属性结果也有影响,要根据具体情况具体分析,通过试验选择合适的灰度级别。另外,灰度级别还会影响程序的计算速度,灰度级别越大,速度就越慢。综合考虑,对于本工区灰度级别取 16或 32为好。

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some proposals are put forward on the options of insite array and inverse interpretation.

Key words: high-density electrical survey; four-electrode array; transverse resolution

FORWARD NUMERICAL MODELING OF SURFACE ELECTRICAL POTENTIAL DISTRIBUTION BY THE BOREHOLE-TO-SURFACE MISE-A-LA-MASSE METHOD

ZHANG Jiong, LI Xue-song (The Geological Exploration institute of Liaoning Metallurical Geology Bureau, Anshan Liaoning 114002, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2010, 32(3): 0284

The thesis introduced our study of forward numerical modeling for three different models by modeling outdoor measurement using borehole-to-surface mise-a-la-masse method and discussed the influence of the anomalous body dynamic variety upon the earth's surface electric potential, the influence of prolong anomalous body on the earth's surface electric potential and the influence of the anomalous body depth variety on the earth's surface electric potential. We carried out theoretical modeling to study the distributing characteristic of the underground low-resistivity body and monitoring water injection pushing direction in the oil-field development by using borehole-to-surface mise-a-la-masse method, and the influence of different stage of oil-field water injection pushing on the earth's surface electric potential. The data of forward modeling can be used for estimating the location of water injection, the direction and attitude of liquid. It is helpful that can make use of posting the water injection in the oil field.

Key words: borehole-to-surface mise-a-la-masse method; forward modeling; oil-field water injection

A TENTATIVE DISCUSSION ON THE DEVELOPMENT AND APPLICATION OF GPR TECHNOLOGY IN CHINA

LI Hua, JIAO Yan-jie, YANG Jun-bo (Chengdu Center of China Geological Survey, Chengdu 610082, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2010, 32(3): 0292

At the beginning of 1980s' of the last century, the ground penetrating radar (GPR) technology had been introduced to China. And now, this technology has been reached a level of maturity. Due to the advanges such as high-resolution, non-destructive, high-efficiency, simple operation, the superiority of anti-interference ability, etc., GPR has been widely used in rapid detection of road quality, tunnel engineering, geological survey field and so on. It has become an important geophysical technique. Based on a lot of previous studies, this paper attempts to make a simple review about the development of ground-penetrating radar technology in China firstly, then analysis of GPR's application field at present. At last, the future develpmental direction of GPR technology is advanced.

Key words: ground penetrating radar; surface-penetrating radar; borehole radar; date processing; application field

ANGLE-DOMAIN COMMON IMAGE GATHERS EXTRACTION AND IMAGING BASED ON G-D WAVEFIELD DECOMPOSITION

LI Dao, ZHANG En-jia, XIONG Xiao-jun (Key Lab of Earth Exploration and Information Technology of Ministry of Education, Chengdu University of Technology, Chengdu 610059, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2010, 32(3): 0300

The usual pre-stack depth migration is realized by the imaging point gathers of offset-domain and shot-domain. By decomposing local plane-wave of G-D wavefield, this article proposed that the local angle-domain imaging point gathers can improve the image quality and effects, and provided a new way for the study of subsurface structure, lithology analysis, and migration velocity analysis.

Key words: G-D frame; angle domain common imaging gather; migration velocity analysis

THE EXTRACTION OF SEISMIC TEXTURE ATTRIBUTE AND ITS APPLICATION IN FAULT IDENTIFICATION

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Texture analysis is a common technology in image processing, which can be extended to the field of geophysical prospecting by constructing seismic texture primitive and gray level co-occurrence matrix. It can be used in fault identification, edge detection and sedimentary facies delineation. Through the algorithm research, programming and practical application, we

get some conclusions which has theoretical meaning and valuable ①The texture attribute which based on gray level co-occurrence matrix is a good attribute in highlighting the information of faults and fractures; ② According to actual geological problems, we can extract texture attributes of different directions, and use RGB technology for the integration of multi-attributes; ③ The window of seismic texture element we should adopt is 9×9×9; ④We should select a reasonable level of gray of different conditions, and commonly selection is 16 or 32 for conventional three-dimensional seismic data

Key words texture; voxel; gray level co-occurrence matrix; RGB technology; faults

THE APPLICATION OF GEOSTATISTICAL INVERSION TO RESERVOIR PREDICTION OF L AREA IN SICHUAN BASIN

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The technique of geostatistical inversion for reservoir prediction is based on geostatistics, and it combines seismic, geologic and logging data to simulate spatial distribution of reservoirs and predict the distribution of reservoirs Through the gas field development of L area in Sichuan Basin, the paper generalizes a inversion route which is based on geostatistics inversion and is suitable for heterogeneous structural-lithological composite gas reservoir of Xujia river in Sichuan basin. It is based on the post-stack restrict sparse pulse determinstic inversion and proceed stochastic simulation of reservoir parameters which takes wave impedance data as the restriction condition and then predict beneficial reservoirs The result shows that this method have the advantage of both high vertical resolution based on logging data and high horizontal resolution based on seismic data and is very helpful for identifying heterogeneous thin inter-bedded sand and shale reservoir

Key words geostatistical inversion; Sichuan basin; stochastic simulation; reservoir prediction

DYNAMIC CHANGES ANALYSIS OF DAMAGED LAND FOR SHIFANG CITY BASED ON REMOTE SENSING AND GIS

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Shifang city as the study area, dynamic changes in land during 2007–2008 has been analysis by using GIS technology and integration of multi-source space data Studies have shown that when the study area is not affected by the external force, the pattern of land use and landscape is relatively stable, but under the secondary disasters due to earthquake and the external force, the deformation of landscape of woodland, open forest land, grassland is larger, and urban land, rural residential areas and farm land is also affected by the earthquake The ideas and researching methods based on remote sensing technology for analysis of dynamic changes of land-use have been applied to the study area, and the results will be the important reference of ecological environment evaluation in the disaster area

Key words RS; GIS; land use; disaster damage; Shifang city

STANDARD CHECK OF QUALITATIVE DATA ON THE MINERAL RESOURCES POTENTIAL ASSESSMENT

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We summarized the results of the national mineral resource potential assessment, and then found that qualitative data are dominant in terms of the number of fields, especially the standard qualitative data Therefore the inspection of qualitative data is important for the national potential mineral resources assessment In this paper, the data check module of the qualitative data in the geological spatial databases is developed using the database dictionary technique which is based on MAPGIS platform. Coding rules and standard of qualitative data are made based on the requirement of national potential mineral resource assessment The standard check of qualitative data is made on the integrity, consistency, accuracy, etc by