·勘探技术·

基于曲率半径法的油田井斜数据处理与应用

隋国华[1,2,3], 隋志强[2], 袁亚娟[1,3], 单 森[4]
(1. 中国科学院 广州地球化学研究所,广东 广州 510640;
2. 中国石化股份胜利油田分公司 物探研究院,山东 东营 257022; 3. 中国科学院 研究生院,
北京 100049; 4. 中国石化集团胜利石油管理局 地质录井公司,山东 东营 257002)

摘要: 复杂断块油气田勘探开发中所钻的斜井是提高勘探开发成功率的重要途径之一,井斜数据用于勘探开发研究时需要进行相关的转换和计算。以实钻资料为依据,通过对比分析正切法、平均角法、平衡正切法、曲率半径法和最小曲率法等 5 种常用的井斜数据处理方法的计算精度,优选出曲率半径法用于胜利油区井斜数据的处理。基于曲率半径法的几何原理,推导了在不同应用条件下相关参数的计算方法和计算公式,解决了井斜历史数据的数字化处理以及井斜数据的综合应用等方面的算法研制问题。通过对其算法进行软件模块封装,在胜利油区勘探决策支持系统和三维地质建模系统中得以调用,应用于井震结合的合成地震记录和层位标定、井位部署中的斜井轨迹显示及设计和斜井钻井工程中的跟踪对比等实际工作中,取得明显成效。

关键词: 曲率半径法 井斜数据处理 勘探决策支持系统 三维地质建模系统 地质应用
中图分类号: TE243.1 **文献标识码:** A **文章编号:** 1009-9603(2011)06-0046-04

据不完全统计,为提高勘探开发效益,胜利油区所钻斜井数量已达数万口,但井斜数据处理因缺乏有效手段制约了其在勘探开发研究中的应用。在油田勘探决策支持系统、三维数据体建模及数据处理系统的研发过程中,笔者以实钻资料为依据,分析对比了正切法、平均角法、平衡正切法、曲率半径法和最小曲率法的计算精度,结果表明曲率半径法与国外厂商的计算结果(其算法不公开)更加接近。据此,基于曲率半径法的几何原理,推导了相关计算公式,并开发出可运行的软件,集成在勘探决策支持系统、三维数据体建模及数据处理系统中,解决了井斜数据的处理及应用问题。

1 井斜数据处理方法

斜井井身轨迹是存在于地下的一条空间曲线[1-4],井斜数据作为对井身轨迹形态的数字表征,是由一系列具有三维空间位置关系的离散测点组成。每一个测点的主要参数包括斜深、井斜角、井斜方位角(方位角)以及垂深、位移偏移量;其中,斜深、井斜角和方位角 3 个参数一般由下井仪直接测出,而测点处的垂深、位移偏移量等其他参数由前 3 项参数根据一定的数学模型计算求得。

在实际钻进过程中,由于测斜工作不能连续进行,因此,只能按一定的间距对井身轨迹上的离散点进行数据测量,再采用数学模型对所测得的离散数据进行处理和拟合,近似表达井身轨迹的空间曲线。一般是用直线、折线或曲线等方式来近似表达。

井身轨迹的计算方法有多种。比较常用的包括正切法、平均角法、平衡正切法、曲率半径法和最小曲率法。前 3 种方法将相邻 2 测点的井眼轨迹视为一条直线或是折线,后 2 种方法将相邻 2 测点的井眼轨迹视为一条空间曲线,而且不同井所对应的空间曲线不相同。为确定井斜数据处理所用的数学模型,获取胜利油区现河庄油田河 50-斜 38 和河 50-斜 34 井等样本井的井斜测量数据,分别基于以上 5 种算法计算各斜井在某一斜深、井斜角、井斜方位角情况下的垂深、南北坐标和东西坐标,计算这 3 项指标与参考指标之间的欧氏距离,分别累加每一深度下的指标值之差的平方,计算结果表明,基于曲率半径法的计算结果与参考值(国外测井仪器得出的结果)最接近(表 1)。

收稿日期: 2011-09-12。
作者简介: 隋国华,男,高级工程师,在读博士研究生,从事勘探信息化方面的研究。**联系电话:** (0546)8552185,E-mail: suiguohua899.slyt@sinopec.com。
基金项目: 国家"863"项目"数字油气田关键技术研究"之"系统集成与数据综合服务、辅助决策应用示范研究"(2009AA062803)。

表 1　5 种井深轨迹算法计算结果比较

算法	垂深	南北坐标	东西坐标
正切法	11.826 7	18.156	27.659 6
平均角法	0.185 462	10.052 8	2.447 75
平衡正切法	0.365 705	1.744 13	2.552 06
曲率半径法	0.026 944	2.351 24	2.486 38
最小曲率法	420.103	66.907 6	117.661

2　基于曲率半径法的相关算法

2.1　任意井斜位置的有关参数计算

2.1.1　井斜角和方位角

根据曲率半径法的几何原理，要求出任意井斜位置处的井斜角和方位角，首先要获取与该位置相邻的前(第 1 个测点)、后(第 2 个测点) 2 个测点的井斜数据(假定这 2 个测点的井斜数据是完备的，即至少已知测点的 6 个井斜参数)，再经一系列推导，才能求出该点的井斜角和方位角。分 2 种情况进行讨论：①如果所求井斜位置与某个测点重合，则直接使用测量的井斜角和方位角数据；②如果跟任意测点均不重合，则根据相邻 2 个已知测点的数据求出该点的井斜角、方位角。

如果 2 个已知测点的井斜角不同，则井斜角的计算公式为

$$\alpha = \frac{\Delta L_2 \alpha_1 + \Delta L_1 \alpha_2}{\Delta L} \tag{1}$$

其中

$$\Delta L_2 = L_2 - L \tag{2}$$

$$\Delta L_1 = L - L_1 \tag{3}$$

$$\Delta L = L_2 - L_1 \tag{4}$$

式中：α 为所求点的井斜角，rad；α_1 为第 1 个测点的井斜角，rad；α_2 为第 2 个测点的井斜角，rad；L_2 为第 2 个测点的斜深，m；L 为所求点的斜深，m；L_1 为第 1 个测点的斜深，m。

方位角的计算公式为

$$\phi = \phi_1 + (\phi_2 - \phi_1)\frac{\cos\alpha_1 - \cos\alpha}{\cos\alpha_1 - \cos\alpha_2} \tag{5}$$

式中：ϕ 为所求点的方位角，rad；ϕ_1 为第 1 个测点的方位角，rad；ϕ_2 为第 2 个测点的方位角，rad。

当 2 个已知测点的井斜角和方位角都几乎一致(或相同)时，式(1)和式(5)分别简化为

$$\alpha = \frac{\alpha_1 + \alpha_2}{2} \tag{6}$$

$$\phi = \frac{\phi_1 + \phi_2}{2} \tag{7}$$

2.1.2　垂深和位移偏移量

根据曲率半径法几何原理，可推导出垂深和位移偏移量计算公式为

$$\Delta H = \Delta L_1 \cos\alpha_v \frac{\sin\frac{\Delta\alpha}{2}}{\frac{\Delta\alpha}{2}} \tag{8}$$

$$\Delta E = \Delta L_1 \sin\alpha_v \sin\phi_v \frac{\sin\frac{\Delta\alpha}{2}}{\frac{\Delta\alpha}{2}}\frac{\sin\frac{\Delta\phi}{2}}{\frac{\Delta\phi}{2}} \tag{9}$$

$$\Delta N = \Delta L_1 \sin\alpha_v \cos\phi_v \frac{\sin\frac{\Delta\alpha}{2}}{\frac{\Delta\alpha}{2}}\frac{\sin\frac{\Delta\phi}{2}}{\frac{\Delta\phi}{2}} \tag{10}$$

其中

$$\alpha_v = \frac{\alpha_1 + \alpha}{2} \tag{11}$$

$$\Delta\alpha = \alpha - \alpha_1 \tag{12}$$

$$\phi_v = \frac{\phi_1 + \phi}{2} \tag{13}$$

$$\Delta\phi = \phi - \phi_1 \tag{14}$$

式中：ΔH 为所求点相对于第 1 个测点的垂深，m；ΔE 为所求点相对于第 1 个测点的东西位移，m；ΔN 为所求点相对于第 1 个测点的南北位移，m。

所求点相对于井口的南北位移和东西位移分别为

$$x = L_{n1} + \Delta N + X_0 \tag{15}$$

$$y = L_{e1} + \Delta E + Y_0 \tag{16}$$

式中：x 为所求点相对井口的南北位移，m；L_{n1} 为第 1 个测点相对井口的南北位移，m；X_0 为井口的纵坐标，m；y 为所求点相对井口的东西位移，m；L_{e1} 为第 1 个测点相对井口的东西位移，m；Y_0 为井口的横坐标，m。

在 GeoFrame 应用中需将 x 和 y 值交换。

2.2　任意垂深位置的有关参数计算

2.2.1　井斜角和方位角

在仅知垂深的情况下，要求出该位置的其他参数，首先要求出对应井位置的井斜角和方位角，然后再利用曲率半径法的计算公式，逐项求出其他各参数值。

如果给定的垂深与其中一个测点的垂深重合，则直接使用测量的井斜角和方位角。如果给定的垂深与任意测点均不重合，则利用式(1)中取出的 2

个已知测点的井斜数据求出该点的井斜角、方位角。

如果 2 个已知测点的井斜角不同，则井斜角的计算公式为

$$\alpha = \sin^{-1}\left(\Delta H_1 \frac{\alpha_2 - \alpha_1}{\Delta L} + \sin \alpha_1\right) \quad (17)$$

其中

$$\Delta H_1 = H - H_1 \quad (18)$$

式中：H 为所求点的垂深，m；H_1 为第 1 个测点的垂深，m。

方位角的计算公式同式(5)。

当 2 个已知测点的井斜角、方位角都几乎一致(或相同)时，计算公式同式(6)和式(7)。

2.2.2 斜深

如果相邻 2 个已知测点的井斜角或者方位角不同，则斜深计算公式为

$$L = \frac{\Delta H_1}{\sin \alpha - \sin \alpha_1}(\alpha - \alpha_1) + L_1 \quad (19)$$

如果相邻 2 点的井斜角、方位角几乎相同，则用平均角法计算斜深，即

$$L = \frac{H - H_1}{\cos\alpha} \quad (20)$$

3 井斜数据的处理及应用

3.1 三维数据体建模及数据处理系统中的井斜数据处理

三维数据体建模及数据处理程序功能包括井斜数据计算和井身轨迹三维可视化[5]。

井斜数据计算包括：①井身轨迹处理计算。按一定格式规范，将原以文件形式保存的完钻井和设计井数据通过处理存入数据库中，允许数据的批量处理，还可允许以不同格式的文本文件方式输出，以满足在 GeoFrame 等解释系统中的应用。②2 点方位计算。根据已知条件，计算井上或井外任意 2 点距离、方位和角度。③井间最小距离计算。计算 2 口井的最小距离、距离最小时 2 个点在井上的位置或坐标，以及 2 点间的方位角、井斜角。④斜深/垂深转换计算。根据一口井的斜深计算纵、横坐标和垂深；输入某口井的垂深计算井对应的斜深位置。

井深轨迹展示包括井集数据管理功能、井身轨迹三维可视化、井斜数据管理功能、保存井身轨迹图形和与生产数据接口，其中三维显示功能可以在三维空间中显示井眼轨迹，可以更直观、形象地观察周围井的井眼轨迹在空间中的位置、轨迹变化和相互关系。

3.2 勘探决策支持系统中的井斜数据处理

勘探决策支持系统是胜利油田自 2006 年开始研发的基于油田勘探信息的综合应用系统，为油田的勘探井位部署、生产管理和综合研究提供了有力支持[6-8]。由于数据库中含有大量的井斜数据，因此，采用以上算法对斜井数据进行了处理，并在工区底图浏览、地震剖面浏览等模块中得到了很好的应用。

3.3 应用实例

3.3.1 井震研究分析

在胜坨油田 X11 断块的井震研究分析过程中，经过处理的井斜数据常用于地质、地震信息的精确关联，奠定了地震属性分析的基础。以测井的声波时差、密度等数据制作合成地震记录，通过与真实的井旁地震道对比、标定，得到合理的时深关系。将计算得到的井轨迹在地震剖面上叠加显示，可以准确地判断钻探地质任务是否完成，钻探的目的层是否准确，通过对比总结含油气层段的特殊地震特征，为区带的含油气性分析提供依据。

3.3.2 井位部署斜井显示及设计

根据完钻斜井的井斜数据，采用合适的速度场数据进行深时转换[9-10]，可以在地震数据体中明确斜井的井筒轨迹。通过对比分析已钻至设计目的层的斜井，可以加深地质认识，指导勘探部署，防止重复部署等失误。另外，为辅助进行井身轨迹设计，工区内设计井井身轨迹与邻井的相对空间位置关系也可以更直观地展示出来。

3.3.3 斜井钻井施工过程跟踪对比

在钻井过程中，通过二维视图显示功能可以绘制井眼轨迹在水平方向和垂直方向的投影图。通过投影图可以查看井眼轨迹在某一方向上的延伸变化和任一深度处的位移偏移数据；通过软件的三维显示功能可以在三维空间中显示井眼轨迹，直观、形象地观察井眼轨迹在空间中的位置、轨迹变化，提高钻井的准确度。通过正钻井的实时测斜数据，可以有效监控探井是否按地质设计要求进行钻进。

4 结束语

在选择井斜数据计算方法时，应充分考虑各算法的适用条件、在不同情况下的计算误差等。根据油田井斜数据处理的精度要求，优选出曲率半径法作为井斜数据的基本计算方法，据此推导出参数计

算公式，全面解决了与井斜数据日常应用有关的算法研制问题。在勘探决策支持系统和三维数据体建模及数据处理系统中都得到切实应用，取得了良好效果。目前，勘探决策支持系统已经成为勘探井位部署和生产管理的日常支持系统，经济和社会效益显著。应进一步研究不同钻井工艺下不同井斜轨迹类型的井斜数据计算方法，使井斜数据的参数求取算法更为精确。

参考文献:

[1] 王礼学，陈卫东，贾昭清，等. 井眼轨迹计算新方法 [J]. 天然气工业，2003，23(增刊)：57-59.

[2] 陈炜卿，管志川. 井眼轨迹测斜计算方法误差分析 [J]. 中国石油大学学报: 自然科学版，2006，30(6)：42-45.

[3] 刘修善，艾池，王新清. 井眼轨迹插值法 [J]. 石油钻采工艺，1997，19(2)：11-15.

[4] 刘修善，石在虹，周大千. 计算井眼轨道的曲线结构法 [J]. 石油学报，1994，15(3)：126-133.

[5] 郭小攀，段天向. 井眼轨迹可视化技术的发展研究 [J]. 特种油气藏，2003，10(5)：54-56.

[6] 隋国华，胡贤根，隋志强. 勘探决策支持系统坐标变换技术 [J]. 油气地质与采收率，2009，16(4)：61-63.

[7] 周霞，申龙斌，孙旭东，等. 油田勘探井位部署决策支持系统应用 [J]. 勘探地球物理进展，2009，32(4)：299-303.

[8] 杨宝真. 垦东 12 平台丛式井组钻井技术难点与对策 [J]. 油气地质与采收率，2008，15(4)：91-93.

[9] 韩宏伟，崔红庄，赵海华，等. 三维速度场建立方法 [J]. 油气地质与采收率，2010，17(1)：54-56.

[10] 侯树杰. 时频分析方法对比及 S 变换在地震数据处理中的应用 [J]. 油气地质与采收率，2011，18(3)：44-46.

编辑　经雅丽

(上接第 45 页)

参考文献:

[1] 赵靖舟. 子北油田长 6 油组砂体分布及相带展布 [J]. 西安石油学院学报，1998，13(1)：11-14.

[2] 武富礼，李文厚，李玉宏，等. 鄂尔多斯盆地上三叠统延长组三角洲沉积及演化 [J]. 古地理学报，2004，6(3)：307-315.

[3] 国吉安，庞军刚，王桂成. 鄂尔多斯盆地晚三叠世延长组湖盆演化及试油聚集规律 [J]. 世界地质，2010，29(2)：277-283.

[4] 曹金舟，任战利，高兴军，等. 鄂尔多斯盆地子北油田洞峪岔地区长 6 油层沉积微相识别与分布特征 [J]. 吉林大学学报: 地球科学版，2010，40(1)：30-36.

[5] 赵靖舟，吴少波，武富礼. 论低渗透储层的分类与评价标准——以鄂尔多斯盆地为例 [J]. 岩性油气藏，2007，19(3)：28-31.

[6] 朱宗良，李克永，李文厚，等. 鄂尔多斯盆地上三叠统延长组富油因素分析 [J]. 地质科技情报，2010，29(3)：75-78.

[7] 王桂成，王羽君. 鄂尔多斯盆地英旺油田长 8 储层非均质性研究 [J]. 西安石油大学学报: 自然科学版，2010，25(5)：16-24.

[8] 于翠玲，林承焰. 储层非均质性研究进展 [J]. 油气地质与采收率，2007，14(4)：15-18.

[9] 方少仙，侯方浩. 石油天然气储层地质学 [M]. 东营: 中国石油大学出版社，2006: 168-180.

[10] 冯伟光. 河流相储层中夹层类型的定量识别 [J]. 油气地质与采收率，2009，16(5)：40-43.

[11] 亓校湘，马德勇，刘雷. 河道砂体内部夹层特征研究 [J]. 大庆石油地质与开发，2005，24(3)：14-16.

[12] 张兴平，衣英杰，夏冰，等. 利用多种参数定量评价储层层间非均质性——以尚店油田为例 [J]. 油气地质与采收率，2004，11(1)：56-57.

[13] 苏玉亮，李涛. 平面非均质性对特低渗透油藏水驱油规律的影响 [J]. 油气地质与采收率，2009，16(1)：69-71.

[14] 郭艳琴，冯娟萍，欧阳征健，等. 姚店油田北区长 6 油层储层特征及分类评价 [J]. 西安科技大学学报，2010，30(2)：197-201.

[15] 庞雯，郭德运，赵靖舟，等. 鄂尔多斯盆地甘谷驿油田东区长 6 油层储层特征及储层评价 [J]. 兰州大学学报，2004，40(5)：96-99.

[16] 黄龙，田景春，肖玲，等. 鄂尔多斯盆地富县地区长 6 砂岩储层特征及评价 [J]. 岩性油气藏，2008，20(1)：83-88.

编辑　经雅丽

0.71% and 0.72% of hydrocarbon source rocks, and the values are equivalent to the maturity of the hydrocarbon source rocks for the third member of Shahejie formation. The study finds that the small secondary depressions in Qinnan sag already possesses high hydrocarbon generation and expulsion capacity, and the exploration prospect should be wider for the adjacent eastern secondary depression that is expected to become one of the main area for the future of petroleum exploration.

Key words: petrophysical feature; geochemical characteristics; oil sources; Qinhuangdao29-2 oil and gas field; Qinnan sag

Yang Haifeng, Department of Technology, CNOOC Tianjin Company, Tianjin City, 300452, China

Liu Ruijuan, Wang Yongshi, Zhang Bo et al. Turbidite sand bodies' characters of petrology and mineralogy and its influence on reservoir physical property in Bonan subsag-case of 0-9 sand groups of Es_3. *PGRE*, 2011, 18(6): 32-36.

Abstract: Using the methods of core observation, thin section identification, scanning electron microscope and X-ray diffraction analysis, we analyzed the clastic composition, clastic texture, interstitial material, etc. Combined with pore structure, reservoir physical property, etc., the influence of the way of turbidite sand bodies' characters of petrology and mineralogy on reservoir physical property is herein studied. The results show that, this area's rock types are mainly debris-feldspar with low compositional maturity and medium textural maturity. With the compositional maturity and textural maturity increasing, the reservoir physical property of turbidite sand body becomes better, while higher contents of rock debris and interstitial material will have negative influence on the reservoir physical property. Therefore, the reservoirs which have a high reservoir physical property should have higher content of quartz, lower content of rock debris, lower content of interstitial material, larger particle size and smaller sorting coefficient. Conversely, the reservoirs have low reservoir physical property.

Key words: turbidite sand bodies; characters of petrology and mineralogy; reservoir physical property; pore structure; Bonan subsag

Liu Ruijuan, Faculty of Geo-Resource and Information, China University of Petroleum (East China), Dongying City, Shandong Province, 257061, China

Zhou Tingquan, Guo Yuxin, Meng Tao et al. Study on Archaean magmatic rocks in Jiyang depression and its conventional logging recognition. *PGRE*, 2011, 18(6): 37-41.

Abstract: The Archaeozoic lithology identification in Jiyang depression is an important part of the Archaeozoic reservoir evaluation and it is difficult to use logging technique to evaluate the igneous and metamorphic reservoirs. Based on detailed research on geologic characteristics of the Archaeozoic magmatic rocks in Jiyang depression, this paper analyses well-logging response characteristics of different lithology, summarizes well-logging response models of various lithology, establishes cross-plot technique, curve overlay technology and the Fisher discrimination method based on statistical analysis, and forms the comprehensive well-logging identification methods on the Archaeozoic magmatic rocks. The accuracy of this method can reach more than 80% in practical application. The method can ameliorate the logging technique for reservoir evaluation in rifted basins and can offer technical support for Archean exploration and reserves report in Jiyang depression in the next stage.

Key words: Archaean; magmatic rocks; lithologic identification; well-logging response; Jiyang depression

Zhou Tingquan, School of Energy Resources, China University of Geosciences, Beijing City, 100083, China

Zhang Fengqi, Wu Fuli, Luo Ranhao et al. Reservoir heterogeneity of Chang4+5^2 and Chang6^1 of Zhaojiatai area in Zibei oilfield, Ordos Basin. *PGRE*, 2011, 18(6): 42-45.

Abstract: Based on casting thin section identification, scanning electronmicroscope, mercury-injection test, core analysis and log interpretation etc, the heterogeneity of Chang4+52 and Chang61 reservoir of Yanchang formation in Zhaojiatai area of Zibei oilfield is studied. It is shown that, there is stronger innerbed, interbed, planar and microscopic hetergeneity in the reservoir, it is controlled mainly by sedimentary facies zone and diagenesis. The innerbed heterogeneity is affected mainly by sedimentary rhythm and interlayers. The interbed heterogeneity is affected by the distribution of barriers and the variation of reservoir property. The planar heterogeneity is closely related with the morphology and connectivity degrees of sand-bodies. Complex pore throat structure affects directly microscopic heterogeneity in the reservoir, and medium pore-fine throat and small pore-fine throat are effective pore-throat types and micropore-micro fine throat is weak pore-throat type.

Key words: *reservoir heterogeneity; Yanchang formation; inner bed, Zhaojiatai area; Zibei oilfield*

Zhang Fengqi, School of Petroleum Resources, Xi'an Shiyou University, Xi'an City, Shaanxi Province, 710065, China

Sui Guohua, Sui Zhiqiang, Yuan Yajuan et al. Study on well deviation data process and field application based on radius of curvature. *PGRE*, 2011, 18(6): 46-49.

Abstract: It's one of the important ways for oil and gas exploration and development to drill deviated wells to improve its success rate in complex fault block of oil and gas field. The measured data of deviated wells needs to be converted and calculated appropriately when they are utilized in the study of exploration and development. Based on the real deviated wells data of Shengli oilfield

to compare and analyze five processing methods in use, such as the tangential method, the average angle method, the balanced tangential method, the minimum curvature method and the curvature radius method. The paper studies and optimizes the radius of curvature as the process approach of deviated wells data. And, based on its geometric principle, it deduces some calculation formula under different conditions, which solves the algorithm problems such as the digital process of historical wells deviation data and the comprehensive application of all deviation data. Consequently, the relevant software module is developed and integrated in the Exploration Decision Support System and in the Three-Dimensional Geological Modeling System. It will be widely used in the synthetic seismogram and horizon calibration among the comprehensive geological study of well-seismic combination, the visualization and design of deviated wells pathway of well deployment and the comparison and track of deviated well drilling project.

Key words: radius curvature; well deviation data process; exploration decision-making support system; 3-D geological model construction; geological application

Sui Guohua, Guangzhou Institute of Geochemistry, Chinese Academy of Sciences, Guangzhou City, Guangdong Province, 510640, China

Luo Huanzhang. Method and application of orientation filtering and noising cancelling. *PGRE*, 2011,18(6):50-52.

Abstract: The current seismic noising cancelling methods are mostly data processing by means of reading the seismic data trace by trace without considering the layer structure information. Orientation filtering method can filter data along seismic events. So, it can improve the SNR of seismic signal more effectively, enhance the continuity of seismic events and show sequence internal model clearly. Firstly, seismic events direction information is estimated by using the gradient structure tensor. Secondly, orientation filter is designed depending on the direction information. Finally, the proposed filter is applied in real seismic data processing. Model and real data application shows that this method can provide high quality seismic data for seismic data processing, and thus has a better practical application value.

Key words: image enhancement; directional information; gradient structure tensor; SNR; resolution

Luo Huanzhang, College of Marine Geosciences, Ocean University of China, Qingdao City, Shandong Province, 266100, China

Bi Junfeng, Wang Shouzhen, Yang Peijie. Application of Wheeler transforming technology in seismic sedimentology-case of sedimentary system of Dongying delta. *PGRE*, 2011,18(6):53-55.

Abstract: By means of flatting and resetting of the seismic events, we can transform seismic data from time domain to wheeler domain so as to study the character of deposition. It enables track all depositional isochronous surfaces automatically and classify the period of delta sands, so as to acquire spatial distribution of depositional system in wheeler domain during the process of studying Dongying delta system by means of seismic sedimentology. Combined with the simultaneous analyses in time domain, all chronostratigraphic events are auto-tracked. Moreover, strata slices increases the insight in the depositional history on isochronous surface, thus, helping the identification of planar distribution character of Dongying delta system.

Key words: seismic sedimentology; Wheeler transform; depositional isochronous surface; strata slice; delta depositional system of Dongying depression

Bi Junfeng, Institute of Geophysics and Geomatics, China University of Geosciences (Wuhan), Wuhan City, Hubei Province, 430074, China

Hou Yongli, Li Xiang, Zhang Yunbao et al. Recovery experiments and application of nitrogen foam-alternating-water process in Bohai oilfields. *PGRE*, 2011,18(6):56-58.

Abstract: Nitrogen foam-alternating-water process is proposed as a potential tapping technology restricted by severe heterogeneity and special operational conditions in Bohai oilfields. As indicated in the experiments, the oil recovery in the foam injection process or following water flooding shows an increasing trend with the decrement of foam slug and the increment of injection rounds, that is, with the total foam volume and water injected, the total oil recovery during the foam-slug injection in three experiments is 5.2%, 8.01% and 12.92% respectively, and 12.89%, 14.69% and 17.35% respectively during the successive water-slug injection. Moreover, the oil recovery in each foam slug increases with the injection rounds, and the total oil recovery is 47.73%, 50.33% and 60%, the increment reaches 20.08%, 23.53% and 31.68%.

Key words: nitrogen foam; alternative injection; flooding; recovery factor; Bohai oilfield

Hou Yongli, Sinochem Oil Liaoning Corporation Limited, Yingkou City, Liaoning Province, 115009, China

Wang Yefei, Xu Huaimin, Yu Haiyang et al. Study on dynamic gelation of hydrophobic associating polymer/ Cr^{3+} gel in porous media. *PGRE*, 2011,18(6):59-62.

Abstract: The gelation time of the gel used for dynamic gelation in porous media is determined through rheometer. The procedure of the dynamic gelation in porous media and the difference between static gelation and dynamic gelation in porous media is studied herein, as well as the influence of permeability and injection speed on dynamic gelation. Results show that the gelation time (6 h)