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储层建模在复杂断块油气藏中的应用 ——以留西油田为例

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摘要: 复杂断块油藏是我国油气田开发中重要的油藏类型之一, 其构造复杂, 隐蔽性强, 描述比较困难。对留西油田属于复杂断块油田, 根据其断层发育、构造复杂、非均质性强等特点, 采用Petrel软件, 以三维地震解释为基础, 充分利用钻井、测井、地层对比等数据, 分析断层在空间的相互切割关系, 建立了三维构造模型, 并利用断点数据对模型进行质量校正, 更加精确地反应了研究区的构造特征。同时, 应用“相控克里金储层参数建模软件”, 建立在沉积相和流体相约束下的储层参数模型。由于采用相控~克里金建模技术, 通过合理添加虚拟井点, 弥补了因实际井点不足造成的预测井间储层参数时出现的误差, 提高了储层模型的精度和准确性, 反映了油藏非均质性特点和油水分布规律, 为精细油藏数值模拟等后续油藏研究奠定了基础。

关键词: 地质建模; 构造模型; 储层参数模型; 相控~克里金

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0 前言

复杂断块油气藏由于发育了众多大小、方向各不相同的断层, 构造破碎, 造成研究此类油藏的构造和储层特征难度较大, 勘探开发难度也大^[1,2]。而储层地质建模技术能对油气储层定量表征, 建立定量精确的三维可视化地质模型, 对井间储层参数进行预测和研究^[3~9]。作者在前期数据收集、高分辨率层序地层与沉积相特征研究的基础上, 应用Petrel软件, 建立了留西油田留416、留17、路44、留80四个断块的地质模型。应用“相控克里金储层参数建模软件”, 建立储层参数模型, 精细刻画了油藏特征, 为后续油田开发和剩余油挖潜提供了依据。

1 地质概况

留西油田位于河北省献县, 为冀中坳陷留西构造带中部留西油田低渗透油层, 断层密集, 断块破碎, 是一个夹持于留路断层和大王庄东断层之间的地堑带, 呈北西向延伸、北陡南缓北高南低的鼻状构造。从北向南, 分成留416断块、留17断块、路43断块、留80断块。区内主要为下切谷、辫状河三角洲和湖相三种沉积相类型^[10]。从前期地质勘探开发和生产效果发现, 留西油田油藏构造破碎, 断层多, 断块多, 勘探开发难度大; 砂层厚度大, 平面变化快, 隔夹层分布不稳定, 储层非均质严重; 油层埋藏深, 平均在3 206 m左右; 储层物性差, 平均渗透率 $17 \times 10^{-3} \mu\text{m}^2$ 左右; 在开发中出现注水压力高, 吸水能力差, 油井能量低, 采液强度低等特点。

2 地质建模

2.1 数据准备

数据是地质建模的基础, 直接影响着模型的质量, 储层建模需要准备的数据主要包括:

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- (1) 井数据: 包括井位数据 ,井斜数据 ,分层数据等。
- (2) 断层数据: 包括断层坐标 ,断点 ,断距等。
- (3) 三维地震解释数据: 主要包括地震解释的层面数据。
- (4) 测井解释数据: 主要包括测井二次解释孔隙度 ,渗透率 ,泥质含量 ,含水饱和度等数据。
- (5) 沉积相数据: 主要包括沉积微相解释和沉积相图。

将各项数据处理整理成为软件要求的数据格式 ,分类导入软件中。

2.2 构造建模

构造建模是储层建模的基础 ,为后面储层相控属性建模提供地层格架模型 ,主要包括断层模型和层面模型。

首先 ,将处理并整理过的地震解释数据和钻井数据导入 Petrel 软件中 ,利用经过三维地震解释的断层数据生成断层面 ,然后转化为断层柱子 (fault stick) ,再选取适当的 fault stick 模拟断层 ,生成 key pillar(见图 1) 。为了保证断层的质量 ,需要用分层数据中的断点数据对其约束。由于留西各区块断层的接触和切割关系比较复杂 ,而 Petrel 软件又不能自动辨别断层之间的关系 ,所以在连接断层之前 ,我们先要确定断层相互之间的关系 ,再将 key pillar 相连接。为了防止在后面网格化时网格出现混乱 ,需要适当调整 pillar 的长度 ,定义好每条断层的断距 ,所有断层 pillar 的顶面和底面应该处在同一平面上。

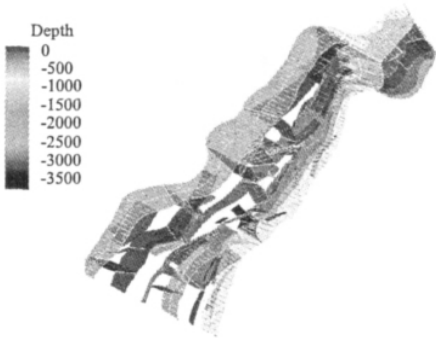


图 1 断层空间格架图
Fig. 1 Framework of fault space

在网格化 (pillar gridding) 前 ,首先要确定好 I 方向和 J 方向 ,一般依据主要断层的走向来确定 ,再添加合理的边界线和趋势线。调整好 Pillar 后 ,以网格步长为 20m × 20m 间距将其网格化 ,生成 2D 平面网格 (见图 2) 。

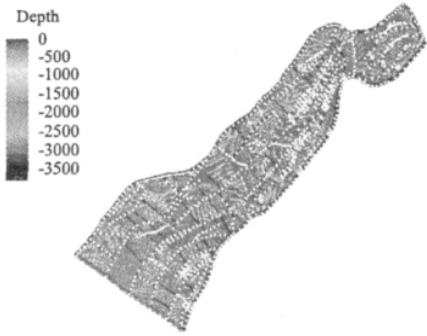


图 2 断层平面网格图
Fig. 2 Grid map of fault plane

观察网格质量 ,是否有错乱的地方。调整 Pillar 和趋势线位置 ,直到网格合格为止 ,生成 3D 网格模型 ,建立断层模型如图 3 所示。然后根据分层数据和地震解释层面 ,建立 3D 层面网格模型。

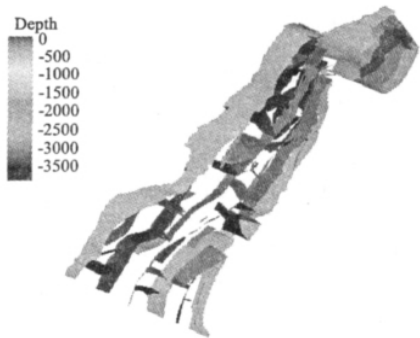


图 3 断层模型
Fig. 3 Fault model

本次研究区内储层共分为三个油组 ,十八个小层。首先根据三维地震解释的顶底构造面 ,在 Make Horizons 中建立三个油组的地层模型 ,然后在 Make Zones 中建立小层模型 ,最后在 Layering 中建立垂向上各小层的三维构造模型 (见图 4) 。

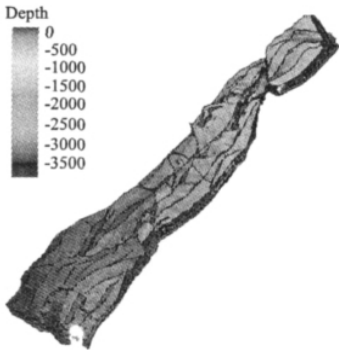


图 4 构造模型
Fig. 4 Structure model

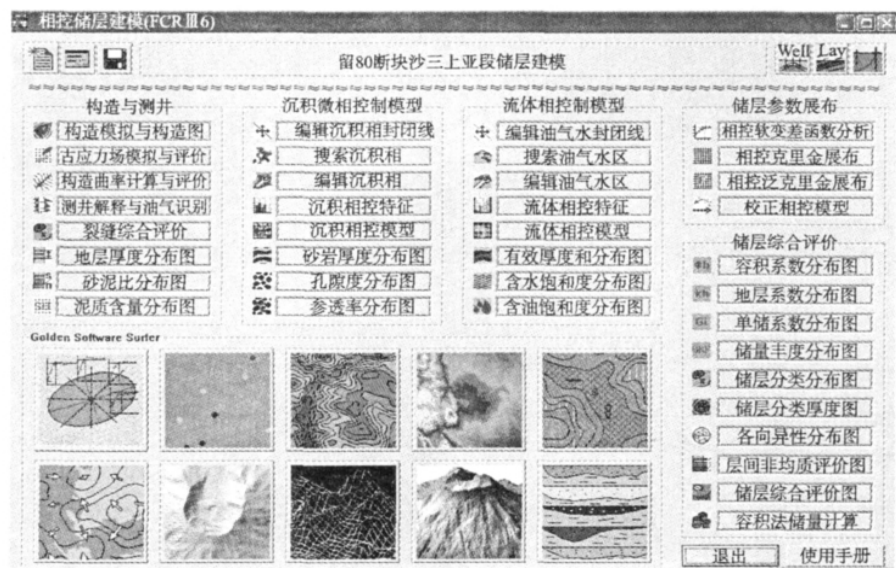


图5 相控克里金储层参数建模软件界面

Fig. 5 Software interface of facies-controlled-Kriging reservoir parameters modeling

2.3 相模型

应用“相控克里金储层参数建模软件”(见图5),建立相模型以及储层参数模型,本次相建模包括了沉积相和油水分布。根据研究,可将沉积微相划分为:泥质沉积、残余砂、主河道、平原辫状河、分流河道、河口砂坝、席状砂、河漫间湾夹层砂、滨浅湖砂坝;油水分布分为:油层、差油层、油水同层、含油层、水层、干层。并分别用不同的数值代表,将其数字化得到相网格模型(见图6)。

2.4 储层属性参数模型

在本次研究中,作者是通过储层的地质特征来约束储层参数分布。即在前面所建的相模型基础上,赋予对应的参数值和概率值,从而建立储层参

数(孔隙度、渗透率、饱和度、有效厚度、夹层)相控模型。用变差函数来描述储集层渗透率、孔隙度等参数的特征,拟合各项参数的理论变差模型。但在建模过程中发现,由于实际井点数据有限,只利用克里金技术预测井间的储层参数,往往和实际有很大差别。因沉积微相和流体相是控制了储层参数变化的重要控制因素,所以为弥补因实际井点少,造成数据展布时的控制不足,需从相模型中提取、添加虚拟井点(见图7)。这样既考虑沉积微相对储层的控制,又考虑到实际钻井对局部变化的控制作用。在实际工作中,还应根据因沉积微相和流体相的变化复杂程度,来确定局部虚拟井的密度。

根据经验,虚拟井与实际井的倍数约为2倍~3倍^[11]。作者本次建模由于区块断层较多,储层

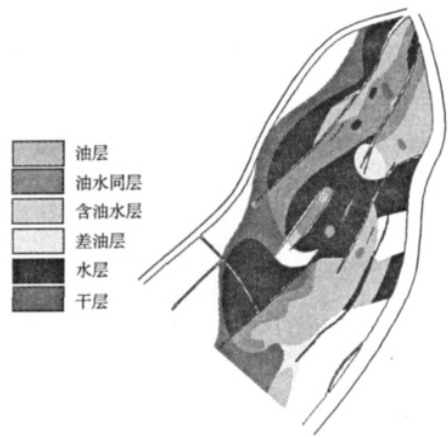


图6 留17断块S324小层油水分布平面图
Fig. 6 Map of oil-water distribution of S324 small layer of block 17

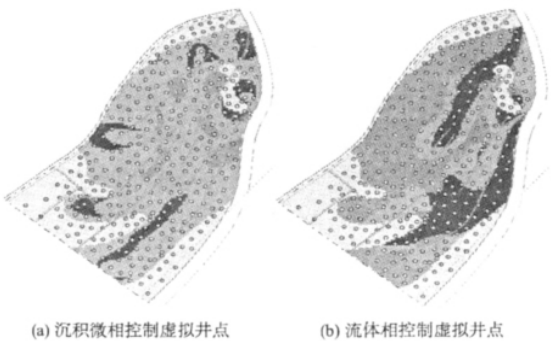


图7 留17断块S325小层相控模型提取虚拟井点图
Fig. 7 Virtual well location map of abstracted from S325 small layer of block 17

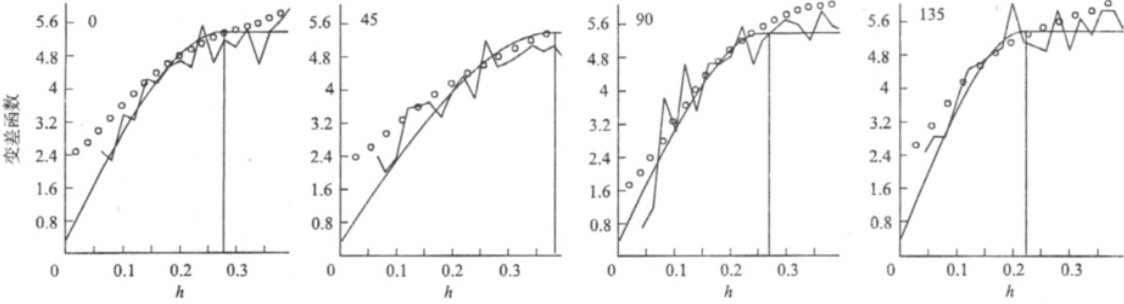


图 8 小层渗透率变差函数拟合
Fig.8 Variogram fitting of small layer permeability

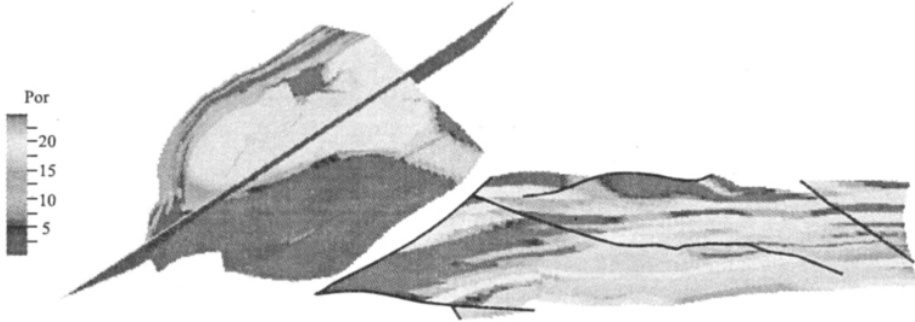


图 9 416 断块孔隙度模型及其剖面图
Fig.9 Porosity model and its profile of block 416

复杂,因此所设置的虚拟井数较多。将实际井和虚拟井相结合后,各物性参数的变差函数更加容易拟合,更接近实际(如图 8 所示)。所以我们采用的是相控~克里金建模技术,对储层进行空间展布,从而得到各个参数的分布模型(见图 9)。

3 结论

- (1) 从地质特征研究入手,作者建立了三维地质模型,直观地展示了储层的三维特征,提高了油藏精细描述的精度,为数值模拟提供了参数模型。对复杂断块油田的储层特征研究具有重要意义。
- (2) 运用相控~克里金建模技术,通过添加虚拟井数据,弥补了实际井点数据不足,提高了井间参数预测的精度,更加合理地描述了储层。
- (3) 相控克里金储层参数建模软件充分考虑了复杂断层和构造对油水分布的控制作用,适用于复杂断块油气藏储层建模。

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OF IP METHOD

ZHANG Wei, LIU Jian-xin, LIU Hai-fei (School of Info-Physics and Geometrics Engineering, Central South University, Changsha 410083, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(3): 309

In practice of mineral exploration and engineering detection, it is typically carried out with no or incomplete prior information. For central gradient array of IP method, it is commonly the case that it is difficult to guarantee anomalous body in the middle of electrodes and that the observation data are affected and deteriorated. Therefore, it is necessary to study the electrode effect on observation data for IP method. This paper studies anomaly curve for IP method with different position between the model and supply electrodes, using experimental research method. The results provide some guidance for practical application and improve the efficiency in implementation of central gradient array of IP method.

Key words: IP method; central gradient array; physical simulation

PROCESSING AND INTERPRETATION OF HIGH DENSITY RESISTIVITY DATA FOR LONG-RANGE SECTION

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In order to enhance the processing and interpretation efficiency with high density data of many adjacent sections on the same measuring line, this paper processes the multi-adjacent data sections through the data merging, 2D interpolation and inversion processing, at last the resistivity 2D inversion data of global section is output to file, and the map is drawn by Surfer software, which make data analysis and interpretation be convenient and prompt. The working efficiency is greatly improved. Through processing the practical data, it is verified that the processing software can be widely used to the practice.

Key words: high density resistivity data; data merging; 2D interpolation; 2D inversion

VOXLER-AIDED 3D-INTERPRETATION OF ELECTRIC SOUNDING DATA IN PINGGU BASIN

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As an important geophysical detection method, electric sounding have been used widely in hydrogeo-

logical, engineering geological, environmental and mineral resources work. However, the traditional data processing method, such as cross-section method, transaction method and section lining method belong to two-dimension manner. In this paper, the main three method and their merits and drawbacks are presented by using the electric sounding data within Pinggu basin. Secondly, the introduction of software Voxler, which is used in this paper, is presented simply. In the end, a sample of 3D model based on all the data of Pinggu region is given. The application results show this interpretation method can characterize the underground geologic body very well. The outcome of the Voxler, which are excellent complement to traditional 2D-data processing methods, can help geologists enhance the studying resolution of subsurface within the working area greatly.

Key words: electric sounding; geologic body; 3D model; voxler

STUDIES ON THE CHARACTERISTICS OF CHANGXING FORMATION ORGANIC REEF-SHOAL COMPLEX IN TONGJIANG TIECHANGHE, SICHUAN BASIN

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The Tiechanghe organic reefs developed in the upper permian Changxing formation are another important representative of platform edge reefs in north-east Sichuan basin. By studying the measurement of 4 outcrops and their detailed indoor examining, this paper finds that the reefs here are not just some isolated reefs like Linchang, and Jiaoshutang, but a united Changxing reef-shoal complex. The Changxing formation is mainly made up by platform edge reefs and platform edge shallow shoal facies, and three upwards vertical cycles reef-shoal complex. The main reef-building organism of the organic reefs is sponge, taking a percentage of about 20% ~ 50%, and fringing reef organism are algae, foraminifer, fusulinida and other categories. Reservoir lithology is mainly made of reef limestones and bioclastic grainstones, with low level dolomitization. Holes are rich, but many were filled with calcite crystals.

Key words: Tongjiang county; Tiechanghe; Changxing formation; sedimentary facies; organic reef-shoal; Puguang gas field

APPLICATION OF RESERVOIR MODELING TO COMPLICATED FAULT BLOCK RESERVOIRS—TAKING LIUXI OILFIELD FOR AN EXAMPLE

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Complex fault oil field is an important kind of oil field in development of Chinese oil field, the structure of this kind of reservoir is complicated with strong elusiveness and is difficult to describe. Liuxi oilfield belongs to complex fault block reservoir because of its characteristics such as highly developing faults, complicated structures and obvious heterogeneity. The software Petrel is used to build its three-dimensional structure model based on 3D seismic data interpretation and the combination with drilling, logging and stratigraphic correlation data, to analysis the crosscutting relationship of the faults on scope, which make the structure feature of the study area more accurately. By use of facies-controlled-kriging reservoir parameters modeling software and facies-controlled-kriging modeling technology, the reservoir parameters model is constructed under the constraints of sedimentary facies and fluid facies. Through using of facies-controlled-kriging modeling technology, adding virtual wells and retrieving the error when predicting the interwell reservoir parameters caused by less of actual well, the structure of the oilfield, heterogeneity property and oil-water distribution are displayed, which have provided basis for the coming reservoir study such as precise reservoir numerical stimulation.

Key words: geology modeling; structure model; reservoir parameters model; facies-controlled-kriging

EVALUATION ON TOTAL AND AVAILABLE CONTENT OF MICRO-ELEMENTS IN PURPLE SOIL OF SANCHI TOWN IN JIANYANG CITY OF SICHUAN PROVINCE

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Taking total and available content of B, Mn, Zn, Cu, Mo elements, content of organic matter and pH value in purple soil of the land consolidation area, Shacha Town, Jianyang city as data base, this paper analyzed the content features of micro-elements in soil, and carried out classification evaluation on available content of these elements. Combining with the correlation between elements' available content and their total content, and organic matter's content, and pH value, the nutrient management suggestions for the study area made. The study indicated that the total content of micro-elements and available content of Mn in the purple soil of this area are relatively normal, while the available content of B, Zn, Cu, Mo elements is badly lacking. Therefore, fertilizer contain-

ing these four elements should be increased in the growth of crops to enhance the agricultural productivity.

Key words: purple soil; micronutrient elements; total content; available content; sancha town; Jianyang city

STUDY OF HIGH-RESOLUTION SBP EXPLORATION FOR SEA SAND RESOURCES IN THE ZHOUSHAN OFFSHORE

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Based on the geological interpretation of sub-bottom profiling which was acquired in study area, The paper divided the shallow strata (or sub-strata) into 4 units with contrasting to drilled data, and have further understanding of the frame of shallow strata in surveying area. Some geological structures which developed in the seafloor such as sand ridges, deposits of tidal channel, sand waves or mat, and those buried under the seafloor are studied in depth, and the discussion to origin of sand resource and supplying of sediments revealed that the sand bodies has characteristics of near-sources deposition and rapid accumulation.

Key words: high-resolution SBP; shallow strata; sea sand resources; Zhoushan offshore

THE DISCUSSION ON CGCS2000 APPLYING TO THE REGION GRAVITY SURVEY

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This paper briefly introduces China geodetic coordinate system 2000 and frame, and also analyzes the influence of Beijing 54 coordinate system on regional gravity survey. On the basis of policy that State Bureau of Surveying and Mapping requires to promote CGCS2000, this paper discusses the new problems on regional gravity survey, and puts forward the solution and suggestion on implementation of CGCS2000. It is proposed that some active and effective approaches should be taken to apply the relevant CGCS2000 coordinates to the work of the regional gravity survey in detailed the technical aspects of exploration and research, and the management system should be developed to promote the regional gravity survey of technological progress.

Key words: CGCS2000; Beijing1954 coordinate system; geodetic coordinate system; coordinate transformation; region gravity survey