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中梯装置供电电极位置对激电法观测结果影响的实验研究

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摘 要: 激电法在矿产勘探及工程探测等实际工作中,经常遇到没有或者工作区域相关资料不完整的情况。尤其是中间梯度装置,无法保证探测目标体位于供电电极中间,其观测数据受到供电电极影响而产生一定的变化,进而影响数据的分析。因此,研究激电法供电电极,对于观测数据的影响规律是很有必要的。这里通过物理模拟手段研究模型相对供电电极 AB 不同位置时的激电异常曲线变化规律,进而指导激电中梯装置的实际应用和提高其生产效率,对激电法中梯装置的应用具有较强的指导意义。

关键词: 激电法; 中梯装置; 物理模拟

中图分类号: P 631.3⁺24 **文献标识码:** A

0 前言

激发极化法是根据岩石、矿石的激发极化效应,来寻找金属和解决水文地质、工程地质等问题的一组电法勘探方法^[1~3]。它分为直流激发极化法(时间域法)和交流激发极化法(频率域法)。激发极化法的应用范围已日益广泛,除寻找铜矿床外,在找铁、找煤、找铅锌矿,以及在超基性岩区找镍铬矿和找金矿等方面,都取得了一定的地质效果^[1,2]。

中间梯度装置是激发极化法中常用的装置。该装置是指当供电电极 AB 位置固定不动时,在 AB 中间 $1/3 \sim 1/2AB$ 范围内进行梯度测量的方法^[4]。中间梯度法不仅在 AB 极所在的测线上观测,而且还可以在相邻测线上观测,但最远的测线一般不超过距 AB 极所在测线的 $1/5AB$ 距离。

中间梯度装置在 AB 中间进行梯度测量。其激发电流场近似的看作均匀场,而在供电电极 AB 附近,激发场为点源场。在野外实际工作当中,大

多情况下对于地下地质情况不了解时,探测目标体距离供电电极的位置不同,其异常曲线会有一定的变化,进而影响异常的分析与解释。此外,中梯装置一次布线仅测量 AB 中间一段区间,这在一定程度上降低了生产效率。因此,研究供电电极附近的激发极化现象,有利于将中梯装置的测量范围扩大到整个 AB 区间,同时也方便了激电异常的分析、解释,进而更大地发挥中梯装置的优势。

1 模拟方法

已知地电模型和场源分布,求解场的分布规律,称为电法勘探的正演问题,它是电法反演问题的计算和观测资料解释的重要基础^[5,6]。地球物理模拟方法按照性质不同,可以分成两大类:物理模拟法和数值模拟法。

物理模拟方法主要有:水槽模拟法、导电纸模拟法等。其中,最为常用的物理模拟方法是水槽模拟法。该法是将模型、装置及场源布置在水槽中进行测量的一种模拟方法。将水槽中的水,近似看作

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均匀介质来模拟实际生产中的围岩,再用具有规则形态的高阻材料或金属材料,来模拟地下高阻体或低阻体。水槽模拟法及土槽法,主要是用于模拟和解决三维问题^[4]。

目前,在地球物理研究中,随着计算机的发展和普及,数值模拟已成为正演模拟的主要手段。但物理模拟方法也不能被忽视,利用物理模拟法所得到的真实结果,可以检验数值模拟结果的可靠性。这两种方法相互补充,可以提高地球物理正演研究的准确性。

2 物理模拟条件及方式

2.1 实验条件

本实验采用的物理模拟方法是水槽模拟,方法采用中南大学何继善院士提出与实现的双频激电法,仪器为继善高科生产的SQ-3C双频道激电仪,工作频率选为4 Hz和4/13 Hz。该仪器的优点在于抗干扰能力强,受电流变化影响小,观测速度快,工作效率高,并且轻便、灵活、稳定性好,观测精度高^[5]。

见图1,实验水槽为5 m×4 m×2 m。模型:球体 $R=11.5\text{ cm}$,球心埋深 $H=10\text{ cm}$ 。

2.2 实验方式

如图2所示,将模型固定不动,首先将模型放置于供电电极AB的中点,模型中心在水面投影为O,即 $A_1O=OB_1$ 。测量电极沿 A_1 点开始向 B_1 点方向进行观测,观测的区间为AB整个内域,观测数据为视极化率 F_s 和视电阻率 ρ_s ,点距为2 cm。因观测设备问题,舍弃靠近 A_1 、 B_1 点的四个点。数据采集完成后,将供电电极AB向B极方向移动一段

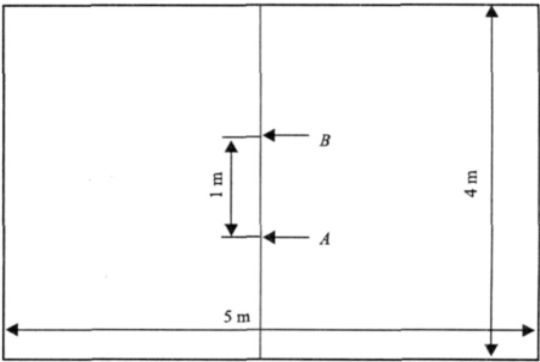


图1 实验水槽示意图

Fig. 1 Diagram of flume Experiment

距离,重新放置AB极,如图2中所示 A_2B_2 。直到测得的异常已经几乎无法分辨为止。

3 模拟结果

3.1 视极化率

下面以低阻极化球体模型的结果为例,说明视极化率 F_s 曲线变化规律,如下页图3所示。

(1)当球体位于AB中心时, F_s 曲线两边对称。随着供电电极AB的移动,电极B慢慢靠近球体, F_s 曲线的强度开始减弱,曲线变缓,且曲线两侧不再对称,远离电极一侧开始变得平缓。当供电电极B跨过球心投影位置后,极化球体位于AB外域时, F_s 曲线的强度继续减弱且变得更加平缓。这是由于球体远离供电电极且激发场较弱,模型激发极化效应较弱所引起的。

(2)当球体位于AB中心时, F_s 曲线的极大值与球体中心投影相互对应,并且曲线两边对称。随着AB的移动, F_s 曲线的极大值相对球心投影位

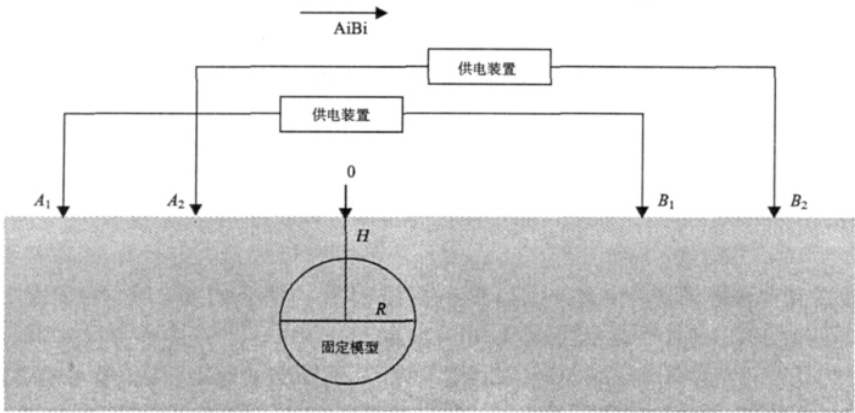


图2 中间梯度装置物理模拟示意图

Fig. 2 Physical modeling diagram of central gradient array

置 $x=0$ 向远离供电电极 B 方向偏移。当供电电极 B 跨过球心投影位置后, F_s 曲线极大值的偏移距离急剧变大,这是因为当球体位于 AB 内域,供电电极 B 靠近极化球体时,地下电流不再是水平状态,极化球体的极化变为像 A 方向倾斜,水平方向上的电位 ΔU 最大值不在球心正上方。当球体位于 AB 外域,供电电极 B 远离极化球体时,球体极化同样不是水平状态,而是变得复杂。

3.2 视电阻率

图 4 和图 5(见下页)分别为低阻极化球体模型和高阻极化球体模型的视电阻率 P_s/P_0 曲线图。

从图 4 和图 5(见下页)中可知,球体模型的视电阻率变化规律如下:

(1) 对于低阻模型来说,当球体位于 AB 中心时, P_s 曲线两边呈对称关系。随着供电电极 AB 的移动,电极 A 慢慢靠近球体, P_s 曲线的异常强度开始增强,曲线中靠近 A 极的部份变得陡立,而靠近 B 极的曲线明显变缓,曲线两侧不再对称,且异常较为明显,如图 5 所示。这是由于供电电极靠近模型,激发电流增强所致。当电极 A 位于球体正上方时,激发电流最强,视电阻率异常值最大。当电极 A 跨过模型后,异常曲线与之前的曲线具

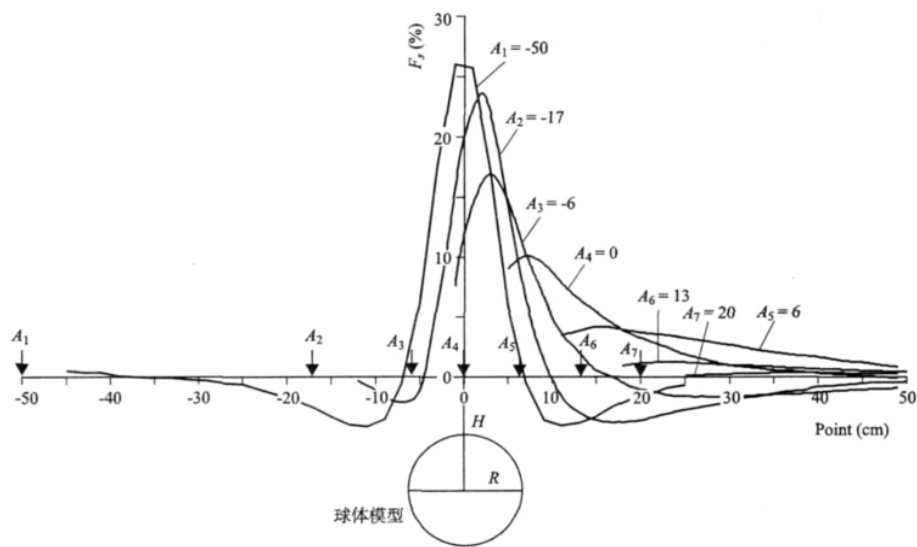


图 3 中梯装置球体模型视极化率曲线图(AB = 100 cm, MN = 2 cm)

Fig. 3 Apparent chargeability curve of spherical model for central gradient array(AB = 100 cm, MN = 2 cm)

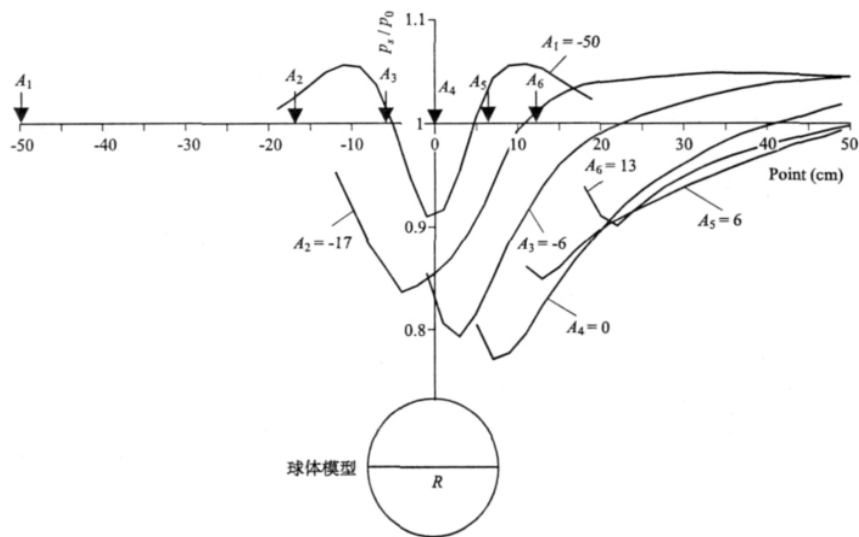


图 4 中梯装置低阻球体模型视电阻率曲线图(AB = 100 cm, MN = 2 cm)

Fig. 4 Apparent resistivity curve of low resistivity spherical model for central gradient array(AB = 100 cm, MN = 2 cm)

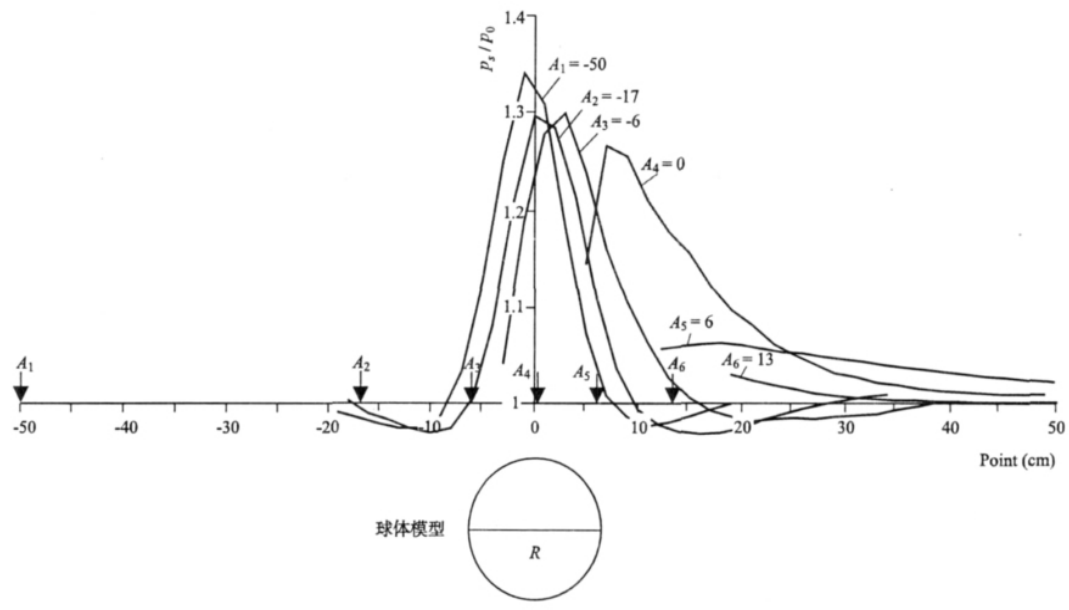


图 5 中梯装置高阻球体模型视电阻率曲线图(AB = 100 cm, MN = 2 cm)

Fig. 5 Apparent resistivity curve of high resistivity spherical model for central gradient array(AB = 100 cm, MN = 2 cm)

有相同的形态,但强度迅速减弱。电极 A 在移动过程中,测得的曲线具有“高~低~高”的特征。当模型在内域时,异常峰值在水面投影点相对于模型中心投影点有一定的偏移。

(2) 对于高阻模型来说,其视电阻率异常曲线与视极化率异常曲线具有相同的规律,但与低阻模型视电阻率曲线具有一定的区别。区别主要在于其最大异常幅值与视极化率相同,都是在模型位于 AB 中点时取得。而低阻球体模型的最大异常值,是模型在供电电极 A 正下方时获得的。

3.3 结果验证

利用描述激电效应引起的复电阻率的频谱公式,即柯尔~柯尔模型,对上述物理模拟实验结果进行验证。

柯尔~柯尔模型是激发极化法正演的基本公式,其表示为式(1)。

$$\rho(i\omega) = \rho_0 \left\{ 1 - m \left[1 - \frac{1}{1 + (i\omega\tau)^c} \right] \right\} \quad (1)$$

式中 ρ_0 为频率为零时的电阻率; m 为充电率,相当于时间域的极限极化率; c 为频率相关系数,量纲为一; τ 为时间常数,具时间量纲^[1,2]。

非极化大地相应条件和装置的直流视电阻率 ρ_s 公式,通过变换可得非均匀大地体积化球体的视复电阻率 $\rho_s(i\omega)$ 的表达式。忽略激电效应,一定装置的直流视电阻率 ρ_s ,可表示为各部份介质电阻率 ρ_j 的函数。当介质被激发极化时,频率域中

各部份介质具有柯尔~柯尔频散形式的复电阻率,见式(2)。

$$\rho_j(i\omega) = \rho_{j0} \left\{ 1 - m_j \left[1 - \frac{1}{1 + (i\omega\tau_j)^{c_j}} \right] \right\} \quad (2)$$

其中 $j = 1, 2, \dots, N$

式中 ρ_{j0} 为介质零频电阻率,即极限等效电阻率; m_j 为介质的(真)充电率,即极限极化率 η_j ; c_j 为介质的(真)频率相关系数; τ_j 为介质(真)时间常数^[3]。

设均匀半空间电阻率为 ρ_1 ,球体半径为 R ,电阻率为 ρ_2 ,主剖面上中梯装置的直流视电阻率 ρ_s 的近似表示式如式(3)。

$$\rho_s = \rho_1 \left(1 + \frac{\rho_2 - \rho_1}{2\rho_2 + \rho_1} \cdot f \right) \quad (3)$$

式中 $f = 2R^3 \frac{r^2 - 3x^2}{r^5}$

当围岩与球体模型产生体极化时,在频率域中,它们的电阻率相应为具有柯尔~柯尔频散形式的复电阻率,如式(4)。

$$\rho_j = \rho_{j0} \left\{ 1 - m_j \left[1 - \frac{1}{1 + (i\omega\tau_j)^{c_j}} \right] \right\} = P_j - iQ_j \quad (4)$$

将式(4)代入式(2)中,可以得到激电效应下的球体的视复电阻率近似表达式:

$$\rho_s(i\omega) = P_1(1 + M \cdot f) - Q_1 \cdot N \cdot f - i [Q_1(1 + M \cdot f) + P_1 \cdot N \cdot f] \quad (5)$$

利用上述方法,可以计算出激电法中梯装置供

电电极不同位置时的视电阻率及视极化率异常曲线。正演模拟的结果与试验模拟得到的曲线,具有相同的曲线形态及变化规律,进而证明实验模拟得到的结果是正确的。

4 实际应用

通过上面的实验结果分析,可以得到激电法中的中间梯度装置视极化率及视电阻率的变化规律。在实际的生产过程中,当异常出现在供电电极 AB 中间 2/3 区间内时,可以根据异常形态,大致划分出异常体的中心位置、范围及其埋深。而当异常出现在供电电极 AB 附近时,根据异常曲线形态划分的异常体中心位置及范围,与其实地位置相比,具有向远离供电电极延伸的特性,从而形成了一定范围的假异常。此种情况可以采用进行全域中梯观测的方法,来确定异常体的真实范围及其埋深。

5 结论

作者在本文中,对激电法中梯装置下供电电极与模型不同位置关系时的异常曲线变化规律进行了物理模拟,并分析了其规律。总结前面的分析结果可知:

(1) 当模型位于 AB 内域,且距离供电电极有一定距离时,中间梯度装置的视极化率 F_s 及其视电阻率 ρ_s / ρ_0 曲线,形态上比较简单,易于分析解释;而当模型靠近供电电极 AB 时,其曲线形态变化相对较大。

(2) 当模型在 AB 中点附近时,其球心在水平面上的投影与曲线峰值点重合;但当模型不在 AB 中点附近时,其曲线峰值与球心投影存在一定的位移,且位移距随模型与 AB 中点的距离的增大而增大。这对于数据解释存在干扰,在实际的生产中需要注意。

(3) 低阻模型视电阻率,都是在模型位于供电电极附近时取得最大异常值;而高阻模型则取得最大异常值是在模型位于 AB 中点。在实际生产中,将供电电极放置在低阻目标体上方,尤其是在目标体与围岩电阻率差异不大的情况下,可起到增大视电阻率异常的作用。

激电法中间梯度装置在应用中可以将测量区间扩大到整个内域,尤其是在普查工作中,即使在缺乏必要地质资料的情况下,通过掌握其曲线的变化规律,仍能反映出异常体的存在和位置。

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tif programming is extremely basic and tedious, while Qt has the characteristics of highly object-oriented and modularization which make the developers easier and programming efficiency higher. Design and development of common processing module integration framework is not only suitable for the migration module integration, but also for others. So the processing module interface style, the operation and the workflow control should be consistent. The main function of the integrated interface includes job deck editing, job submission, job deletion, job monitoring and some auxiliary functions. After we abstract processing module parameters highly, the module additions and modifications become very simple by using the resource file approach and module registration. We do not need to compile the control interface repeatedly, so the system's transplant and the maintenance are very convenient.

Key words: migration system; resource file; job manage; integration interface; modul register

NATURAL NEIGHBOUR INTERPOLATION AND ITS APPLICATION TO 2D GRID OF IRREGULAR DATA

ZHANG Wei, QIN Qing-yan, JIAN Xing-xiang (College of Information and Engineering, Chengdu University of Technology, Chengdu 610059, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(3): 291

As the observation data is insufficient, two-dimensional interpolation of irregular discrete data is widely used in geophysics. In this paper, we researched and implemented a two-dimensional interpolation of Natural Neighbour algorithm, which will be applied to the MT 2D inversion real-time imaging. Example results show that the method has high accuracy, effective, fast and easy simulation of the data with terrain.

Key words: natural neighbours; 2D interpolation; data gridding

RESEARCH AND IMPLEMENTATION OF GIS-BASED LONG-PERIOD MAGNETOTELLURIC VISUALIZATION DATA MANAGEMENT PLATFORM

QIN Qing-yan, ZHANG Wei, WANG Xi-chong (College of information Engineering, Chengdu University of Technology, Chengdu 610059, China). *COMPUTING TECHNIQUES FOR GEOPHYSICAL AND GEOCHEMICAL EXPLORATION*, 2011, 33(3): 296

The paper proposes a method which applies database and GIS technology on the visual management of LMT data contrary to the shortcomings of traditional information management methods, which integrates survey sounding location with different spatial data sources such as administrative areas information, traffic information, digital elevation and tectonic information. The paper introduces the principle and process of the platform's implement, and also describes the

realization of survey points' plane projection and survey line's straight fitting. Application results show that the platform not only effectively manages data in simple and graphical ways, but also provides necessary information for the field production and data's qualitative processing and interpretation.

Key words: long-period MT; GIS; survey line projection; geological background

GUPTASARMA LINEAR FILTERING ALGORITHM IN CSAMT ONE-DIMENSIONAL FORWARD MODELING

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The basis of One dimension CSAMT forward problem is the Hankel transformation. Now the main solution to this problem is numerical filtering method, which runs the process of solving the given length of filter coefficients for additive operations. Therefore, the selected filter coefficients affect the precision and speed of the forward calculation. In this paper we use the Guptasarma linear filter coefficients and implement the algorithm. It's verified by the models that it fits well with the forward models with a relatively short length of filter coefficients, which makes a good basis of the next work in inversion or quasi two - dimensional problem.

Key words: CSAMT; one-dimensional forward calculation; fast hankel transformation; numerical filtering

DETERMINATION OF THE SPACE TREND FOR DEPTH ORE BODY BY THE ULTRA-HIGH DENSITY RESISTIVITY

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Ultra-high density resistivity method is a new geophysical method, the method is convenient, fast, effective, large data amount and so on. Because of the complex geologic structure and the surface topography, ore body space trend and connection is difficult to be determined. By using the well to well ultra-high density resistivity method, we have obtained the expectation result.

Key words: ultra-high density resistivity method; determination of depth ore body space trend; data excavate; repeat demonstrate; mine connection

EXPERIMENTAL STUDY ON THE IMPACTS OF ELECTRODE POSITION ON ANOMALY CURVES FOR CENTRAL GRADIENT ARRAY

OF IP METHOD

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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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