电阻率时间推移测井解释方法研究

陈福煊 西南石油学院

摘 要 电阻率时间推移测井是一种能消除复杂岩性、复杂孔隙结构和厚层围岩影响，并能划分出油、气、水层的较好方法。但目前该解释方法还欠完善。从泥浆滤液侵入剖面的基本状况和条件入手，考虑粒间孔隙储层、裂缝性储层、油层和气层侵入剖面的差异，得出了电阻率时间推移测井定性、定量解释方法。对粒间孔隙储层而言，可不考虑泥浆电阻率和相对密度变化的影响；但对裂缝性储层还需考虑这两个因素的影响。测井时，掌握两次测井的时间十分重要，第一次测井时间选在滤液侵入储层较浅时，第二次选在侵入较深时。应用该法对塔里木油田数口井测井资料进行解释，其结果与试油资料相吻合，表明该法具有极大的运用和推广价值。

主题词 时间推移测井 储集层 油气层 识别

为了识别油气田中的复杂油、气、水层，电阻率时间推移测井方法不时被人们利用。但据目前的文献报道，该方法的定性解释方法受到泥浆电阻率、泥浆相对密度以及滤液侵入储层时间长短等因素的干扰，解释结果不十分可靠；此外，定量解释方法也未建立。本文着重研究了这方面的问题。

$$G = \sum M_i S_i$$

式中：G 为天然气区集总储量($10^8 m^3$)；

M_i 为含气面积内某一储量丰度等值线值；

S_i 为与之相应的等值线所包络的面积(km^2)。

由此可精确计算出各块天然气地质储量。

综 合 评 价

从整体上看，中部气田奥陶系风化壳马五$_1$ 气藏为低孔、低渗、低丰度、深层大气田。其各项指标如下。

(1)气层薄，单层厚度一般小于 3 m。

(2)孔隙度为 3%～8%。

(3)渗透率为(0.03～16.33)$\times 10^{-3} \mu m^2$，局部层段可达 $300\times 10^{-3} \mu m^2$ 以上。

(4)含气饱和度 75%～80%。

(5)含气面积广，总计数千平方公里。

(6)单储系数为(0.0538～0.231)$\times 10^8 m^3/km^2 \cdot m$，平均为 $0.108\times 10^8 m^3/km^2 \cdot m$；储量丰度为(0.027 6～1.457)$\times 10^8 m^3/km^2$，平均为 $0.538\times 10^8 m^3/km^2$，属低丰度范围。

(7)地层压力为 30.79～32.21 MPa，平均为 31.6 MPa，最大压差 1.42 MPa，压力系数小于 1。地层温度为 105～113℃。气层埋深逾 3 000 m。

(8)累积基本探明储量已逾 1 000 亿 m^3，属大气田。

从区域上看，中部气田仍有向南、北方向作较大的延伸趋势，气田边界至今仍不明朗，预计可南达延安，北抵乌审旗。

中部气田气藏描述是一项新技术推广项目，是集体劳动的结晶，在此向关心和支持这项工作的各界人士及参与工作的同仁们表示诚挚的谢意。

参 考 文 献

1 曾少华等. 陕甘宁盆地中部气田奥陶系风化壳碳酸盐岩储层地质概念模型. 天然气工业，1993；(5)

2 黄月明. 陕甘宁盆地中部气田白云岩储层特征. 天然气工业，1993；(5)

3 蒋加钰，程光清. 陕甘宁盆地中部气田奥陶系风化壳储层地震横向预测. 天然气工业，1993；(5)

曾少华，高级工程师，1963 年生；1983 年毕业于江汉石油学院地质系，现从事油气储层及气藏综合描述工作，曾在《天然气工业》《沉积学报》等刊物上发表论文多篇。地址：(745101)甘肃庆阳。

(审稿人 教授级高级工程师 唐泽尧
本文收稿 1994—10—15 编辑 居维清)

解释方法原理

1. 定性解释

泥浆滤液侵入地层的影响因素很多，造成了侵入剖面的复杂性。为了研究普遍适用的电阻率时间推移测井解释方法，我们从侵入剖面的基本关系和条件入手，考虑粒间孔隙储层、裂缝储层、油层和气层侵入剖面的差异，建立电阻率时间推移测井解释方法。

假定泥浆滤液的电阻率为 R_{mf}，冲洗带与侵入带相同，其含水饱和度为 S_{xo}，地层水电阻率为 R_w，原始含水饱和度为 S_w，地层为纯地层，地层因素为 F，则按阿尔奇定律分别在侵入带和原状地层有：

$$R_{xo}=\frac{F\ R_{mf}}{S_{xo}^2} \qquad (1)$$

$$R_t=\frac{F\ R_w}{S_w^2} \qquad (2)$$

两式相除得：

$$\frac{R_{xo}}{R_t}=\frac{R_{mf}}{R_w}\left(\frac{S_w}{S_{xo}}\right)^2 \qquad (3)$$

对于中等密度的烃有：

$$S_{xo}=S_w^{1/5} \qquad (4)$$

则得

$$\frac{R_{xo}}{R_t}=\frac{R_{mf}\ S_w^{8/5}}{R_w} \qquad (5)$$

由(5)式可见，侵入剖面的高、低侵特征不但与 R_{mf}/R_w 值有关，而且与储层含流体性质(S_w)有关。因此，可用目的层侵入带与原状地层电阻率的高、低侵特征来定性判断它是油气层或是水层。但是，在作此判断时应注意以下几点：

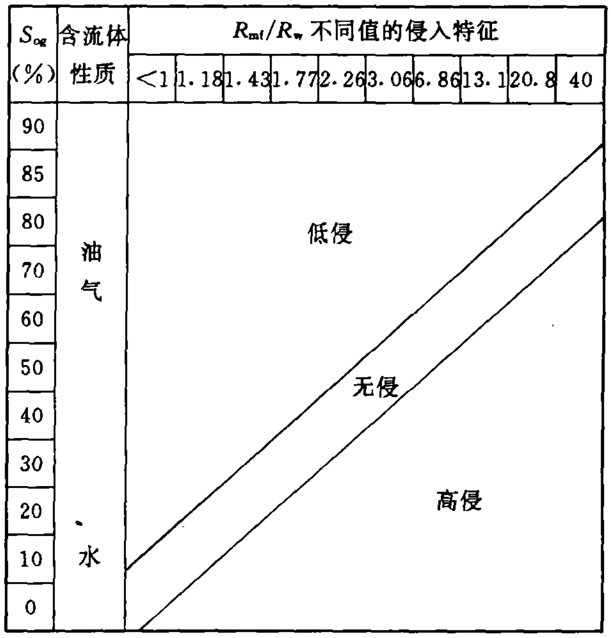
(1)R_{mf}/R_w 值对储层高、低侵特征的影响。这一影响概括在表1中。由表1可见，只有 $R_{mf}/R_w \cong 2.5$ 时，高低侵特征才与储层的含流体性质相匹配。否则，当 $R_{mf}/R_w > 2.5$ 时，油气层也可能是高侵水层特征；当 $R_{mf}/R_w < 2.5$ 时，水层也可能是低侵油气层特征。

(2)R_{mf}在不同类型储层中的变化情况。对于粒间孔隙储层，井壁上的泥饼对侵入起控制作用。当第二次测井泥浆电阻率和相对密度变化不大时，不会改变已侵入较深的滤液电阻率和侵入半径。因此在用探测深度中等的电阻率测值(R_M)代替 R_{xo}时，滤液电阻率可始终认为是第一次测井时的滤液电阻率(R_{mf1})。但是，对于裂缝性储层则不然，泥浆可直接进入裂缝较深处，而井壁很难形成泥饼，裂缝中的流体可认为是每次变化了的泥浆，而储层基块孔隙中又可能是第一次侵入的滤液。

(3)在裂缝储层中，泥浆相对密度变化对侵入半径影响明显。第二次测井的泥浆相对密度增大会使侵入半径加大；相反，相对密度减小，侵入半径减小，油气回到井壁附近。特别是天然气层，天然气流动性比油更大，对泥浆相对密度变化更敏感。

表1　一般油、气、水层侵入剖面特征与 R_{mf}/R_w 关系表

Table 1. Relation between the invasion profile features and R_{mf}/R_w of ordinary oil/gas/water layer



(4)在相同条件下，油层侵入半径较水层和气层浅；高、低孔隙度地层较中等孔隙度地层侵入浅。滤液侵入地层深浅会对 R_{xo}和 R_t 两种电阻率测值的代表性产生影响，进而造成解释的失误。

2. 定量解释

电阻率时间推移测井资料的定量解释，可根据(5)式计算目的层的含油气饱和度(S_{og})。其条件是已知目的层的 R_{mf}和 R_w 值，以及 R_{xo}和 R_t 的近似测值。

R_{mf}值可用常规地面泥浆电阻率测量值(R_m)推算，R_w 值可用常规水样分析换算或测量，R_{xo}和 R_t 的近似测值分两种情况取得：

(1)设第一次测井比较及时，滤液侵入储层浅，深电阻率(R_{D1})代表 R_t；第二次测井滤液侵入深度与深电阻率探测深度相当，深电阻率测值(R_{D2})可作 R_{xo}的近似值，且第二次测井在离井壁较深处滤液电阻率是 R_{mf1}。根据(5)式则有：

$$\frac{R_{D2}}{R_{D1}}\cong\frac{R_{xo}}{R_t}=\frac{R_{mf1}\ S_w^{8/5}}{R_w}$$

即

$$\begin{cases} S_w=\left(\dfrac{R_{D2}\ R_w}{R_{D1}\ R_{mf1}}\right)^{\frac{5}{8}} \\ S_{og}=1-S_w \end{cases} \qquad (6)$$

(2)设已知第 i 次测井的深、中探测电阻率是 $R_{D(i)}$ 和 $R_{M(i)}$，它们分别不同程度接近 R_t 和 R_{xo}($i=1,2,3,\cdots,n$)。并可用侵入校正图板求每次的侵入半径 $r_{i(i)}$，根据(5)式有：

$$\frac{R_{M(i)}}{R_{D(i)}}\cong\frac{R_{xo}}{R_t}=\frac{R_{mf1}S_w^{\%}}{R_w}$$

即

$$\begin{cases} S_{w(i)}=\left(\dfrac{R_{M(i)}R_w}{R_{D(i)}R_{mf1}}\right)^{\frac{5}{8}} \\ S_{og(i)}=1-S_{w(i)} \quad (i=1,2,3,\cdots,n)\end{cases} \quad (7)$$

$$\begin{cases} \text{油气层 } r_{i(i+1)}\geqslant r_{i(i)}\text{时}, S_{og(i+1)}\leqslant S_{og(i)}<1 \\ \text{水\ \ 层 } r_{i(i+1)}\geqslant r_{i(i)}\text{时}, S_{og(i+1)}\cong S_{og(i)}\cong 0\end{cases} \quad (8)$$

(6)和(7)式是电阻率时间推移测井定量解释含油气饱和度(S_{og})的公式。(8)式可作油气层和水层的判据。

解释实例

1.砂岩储层

图1为塔里木油田C井砂岩储层的电阻率时间推移测井图。该井的已知数据如表2。

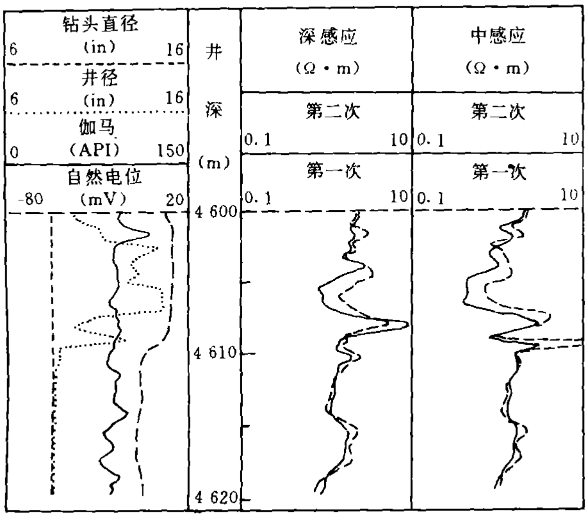


图1 C井砂岩储层电阻率时间推移测井曲线

Fig.1. Resistivity time-lapse logging curves of Sandstone reservoirs of well C.

(摘自文献[2])

表2 C井已知数据表

Table 2. Known data of well C

测井第次	时　间	R_{mf} (Ω·m)	G_m (g/cm³)	R_{mf}/R_w	R_w (Ω·m)
1	1990年3月18日	0.058	1.2	4.4	0.0133
2	1990年5月18日	0.131	1.6	10.1	0.0133

注：试油结果在4 609～4 621 m井深产油125.5 m³/d，气7 150 m³/d。

用(5)式作定性解释如下：由 $R_{mf1}/R_w=4.4$ 和表1可知，含油气饱和度为50%以下的储层都为高侵显示。因此，C井从4 609～4 621 m井段可能是高侵油气层；而4 614～4 618 m井段则是低侵显示的高含油气层。

用(6)式和(7)式作定量解释如表3。从定量解释的含油气饱和度和定性解释结果与试油气资料对照看，结论是一致的，该井段是油气层。

表3 C井定量解释 S_{og} 数据表

Table 3. Quantitative interpretation S_{og} data of well C

井　段 (m)	R_{D1}/R_{D2}	R_{M1}/R_{M2}	(6)式算 S_{og}	(7)式算 S_{og}	结　论
4 612～4 614	1.1/1.2	1.3/1.5	58%	56%	油气层
4 614～4 618	2/1.5	1.6/1.4	67%	66%	油气层
4 618～4 621	0.62/0.7	0.8/0.9	57%	54%	油气层

2.碳酸盐岩裂缝储层

这种储层的井壁泥饼很少，泥浆柱压力变化对侵入深度有较大的影响，电阻率时间推移测井资料可分成两种解释方法来解释。

(1)减压测量法($p_{m1}-p_{m2}>1.2$ MPa)

第二次测井时泥浆相对密度减小，泥浆柱压力(p_{m2})比第一次测井时的泥浆柱压力(p_{m1})减少1.2MPa以上，这样储层中的油气就会回到井壁附近。如果把第一次深侵的深电阻率(R_{D1})看成侵入带电阻率(R_{xo})的近似值，而第二次油气回流时测井的深电阻率(R_{D2})看成原状地层电阻率 R_t，则用(6)式可得含油气饱和度计算公式：

$$\begin{cases} S_w=\left(\dfrac{R_{D1}R_w}{R_{D2}R_{mf1}}\right)^{\frac{5}{8}}=\left(\dfrac{R_{xo}R_w}{R_tR_{mf1}}\right)^{\frac{5}{8}} \\ S_{og}=1-S_w\end{cases} \quad (9)$$

图2是减压测量法D井碳酸盐岩裂缝储层的电阻率时间推移测井实例。该井已知数据如表4，定量解释结果如表5。

由表4可知，D井第二次测井时的泥浆密度较第一次低，泥浆柱压差低2.5 MPa，导致第二次测井时油气回流到井壁附近，所测深电阻率(R_{D2})可视为原状地层电阻率(R_t)；而第一次在较大压差下泥浆侵入深，深电阻率(R_{D1})反映侵入带电阻率(R_{xo})。并且该井 R_{mf1}/R_w 值为3.41。根据表1，侵入剖面的高、低侵特征正好与储层含流体性质对应，高侵为含

水部分；相反，低侵为含油气部分。底水上界面在5 249 m。再按公式(9)定量计算各深度含油气饱和

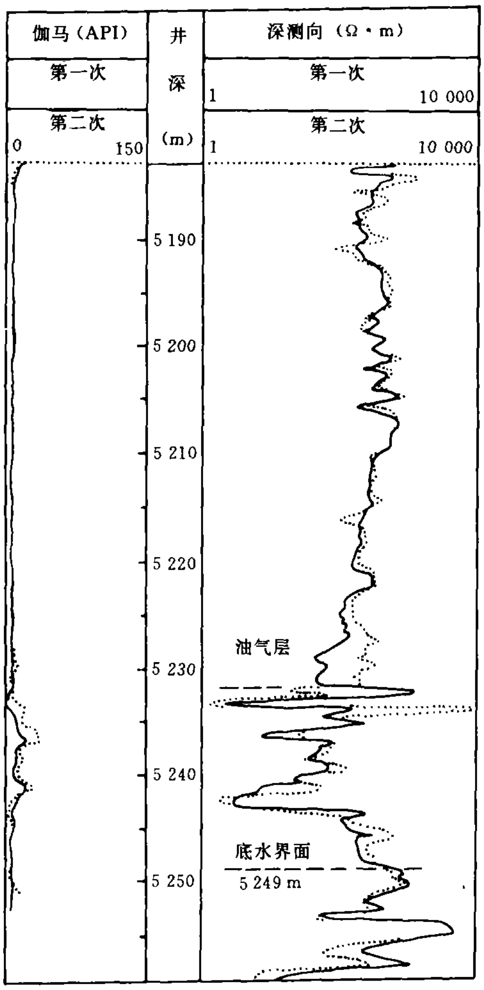


图2 D井碳酸盐岩裂缝储层电阻率时间推移测井图

Fig. 2. Resistivity time-lapese logging of fractured carbonate reservoirs of well D.

(摘自文献[2])

表4 D井已知数据表

Table 4. Known data of well D

测井第次	时 间	井深 (m)	泥浆数据		R_w (Ω·m)
			R_{mf} (Ω·m)	ρ_m (g/cm³)	
1	1989年7月17日	5 150～5 264	0.045 4	1.2	0.013 3
2	1990年6月6日	5 167～5 266	0.008 8	1.15	0.013 3

注：中途测试：5 179～5 230m 产油 376m³/d，气 9×10⁴m³/d；
完井测试：5 179～5 266m 产油 554.8m³/d，气 17×10⁴m³/d。

度(S_{og})如表5。它也显示了定性解的结论，并且与中途测试结果基本一致。但是，底水界面与完井试油气有些出入，这可能是裂缝系统的复杂性所致。

表5 D井测井解释结果表

Table 5. Log interpretation results of well D

井 深 (m)	R_{D1} (Ω·m)	R_{D2} (Ω·m)	S_w (%)	S_{og} (%)	结 论
5 190	200	250	40	60	油气层
5 210	600	600	46	54	油气层
5 232	80	250	23	77	油气层
5 238	80	110	38	62	油气层
5 243	3	2	59	41	水平裂缝
5 247	200	300	36	64	油气层
5 249	900	600	59	41	底水界面
5 254	50 000	1 000	126	0	水层
5 256	200	50	110	0	水层
5 257	1 100	300	104	0	水层
5 260	10	5	71	29	水层

另外，从定量计算的 S_{og} 可知，含油气部分中裂缝发育井段两次测井电阻率都很低，且随泥浆电阻率变化而变化，这是裂缝地层特征。然而裂缝不发育井段电阻率较高，两次测井电阻率差异较好地反映了储层中含流体特性。

(2)等压和增压测量法

第二次测井泥浆相对密度等于或大于第一次测井的泥浆相对密度时，则滤液侵入过程始终向着地层深部。如第一次测井时侵入较浅，深电阻率(R_{D1})接近 R_t；第二次测井时侵入较深，深电阻率(R_{D2})接近 R_{xo}，则可用(7)式解释含油气饱和度(S_{og})。两次测井泥浆侵入都较深或较浅时，两次深电阻率曲线无幅度差，则可用第一次的深、浅电阻率(R_{D1}、R_{S1})以及公式(8)来计算含油气饱和度(S_{og})。

电阻率时间推移测井是一种能消除复杂岩性、复杂孔隙结构以及厚层围岩影响，并能划分出油、气、水层的较好方法。实践证明，该方法值得在油气田进一步验证和推广使用。

参 考 文 献

1 谭廷栋. 电阻率时间推移测井. 测井技术，1979；(6)

2 顿新忠. 电阻率时间推移测井在塔里木石油勘探开发中的应用. 国外测井技术，1993；(5)

3 Tobola D P *et al*. Determination of reservoir permeability from repeated induction logging. SPE，19606

4 Campbelc W M，Martin J L. Displacement logging—a new exploratory tool. Trans ALME，1955；204

陈福煊，1940年生，副教授；1963年毕业于北京石油学院地球物理测井专业；曾发表论文十余篇，主持和参加国家、部级科研项目近十项，现从事地球物理测井科研和教学工作。地址：(637001)四川省南充市。电话：(0817)2224433转2855。

(修改回稿 1995—07—21 编辑 韩晓渝)

following:①The Tertiary Sha 3 member and Sha 4 upper member in the area are the main oil source beds. Gegangji depression to the east is the main oil-gas source area. ②The hydrocarbon generated in the depression at the early stage has migrated and accumulated to the upper section of the structure to form Sha 3 member oil-gas reservoir under the differential pressure caused by shale undercompaction. The secondary oil-gas reservoirs of Sha 1 and Sha 2 members were formed as the violent rifting at later stage made hydrocarbon migrate along faults. ③Litun fault with an intenser sealling, located on the east side of the structure, was formed earlier mainly generating gas at later stage. The generated gas sealed by Litun fault formed Sha 3 gas reservoir with fault-stratum trap in the deep place in the east to make the oil-gas appear the distribution of "gas under oil and top oil with edge gas".

SUBJECT HEADINGS: Dongpu Sag, Qiaokou oil field, Tertiary, Oil-gas distributioin, Migration.

Lei Li' an, engineer, graduated in geology department from Northwest University in 1985; Now he is engaged in the comprehensive study of oil field development geology. Add: (457001)No. 157, Zhongyuan Rd., Puyang City, Henan. Tel: (0393)4816117.

Hao Shumin(*The Third Petroleum Survey Team of the Ministry of Geology and Mineral Resources*), Si Jianping, Li Jiefu:**SEISMIC FACIES OF THE LOWER ORDOVICIAN UPPER MAJIAGOU FORMATION IN THE NORTH PART OF EERDUOSI BASIN**, NGI 16(1), 1996: 14~18

ABSTRACT: The Ordovician internal structures in the north part of Eerduosi Basin are not well developed. The regional seismic sections are mainly characterized by parallel reflecting configurations. Through analysing the fases T_9 and T_{10} which respectively represent the top and the bottom of Upper Majiagou formation and the secondary fases between T_9 and T_{10}, 3 seismic facies areas and 11 seismic facies types can be divided in the north part of the Basin. The different types of seismic facies represent the reflecting configuration characteristics of the different sedimentary facies and lithological association on seismic sections. The sedimentary sequence and facies evolution in unexplored areas can be clarified by dividing the seismic facies types in the drilled areas to provide a basis for optimizing exploration areas. According to the regional characteristics of dolomite reservoirs in upper Majiagou formation in the north part of the Basin, 6 seismic facies i. e. B, D, E, F, I, J, can be classified as areas suitable for the development of dolomite which are also favourable for natural gas exploratin.

SUBJECT HEADINGS: Eerduosi Basin, North, Early Ordovician, Reservoir, Seismic facies, Stratigraphic classification.

Hao Shumin, senior engineer, graduated in the Petroleum Department from Chengdu Geology Institute in 1982; At present, he is engaged in the comprehensive researches on oil-gas exploration. Add: (712000) No. 10, East Biyuan Rd., Xianyang, Shanxi. Tel: (0910)212997—353.

Zeng Shaohua(*Exploration and Development Institute of Changqing Petroleum Exploration Bureau*), Chen Anning, Jiang Jiayu, Yang Guozhong: **CHARACTERIZATION OF ORDOVICIAN WEATHERING CRUST GAS RESERVOIR IN THE CENTRAL GASFIELD OF SHANGANNING BASIN**, NGI 16(1), 1996: 18~25

ABSTRACT: Characterization of Ordovician carbonate gas reservoir is carried out in the following steps: Firstly, sedimentary description, trap description and reservoir description of $O_1m_1^5$ gas reservoir have been done by combination of geology, well logging, seism and mathematical geology. Then the gas in place is accurately calculated. Finally the gas reservoir is comprehensively evaluated. In conclusion, the gas reservoir of interest is a large-scale gas field with low porosity, low permeabitity, low abundance and great depth.

SUBJECT HEADINGS: Eerduosi Basin, Middle, Gas field, Ordovician, Gas reservoir, Gas reservoir description, Gas reservoir evaluation.

Zeng Shaohua, senior engineer, graduated in geology department from Jianghan Petroleum Institute in 1983; At present, he is engaged in petoleum reservoir research. Add: (745101)Qingyang, Gansu.

Chen Fuxuan (*Southwest Petroleum Institute*): **INVESTIGATIONS ON THE INTERPRETATION METHOD OF RESISTIVITY TIME-CAPSE LOGGING**, NGI 16(1), 1996: 25~28

ABSTRACT: Resistivity time-lapse logging is a better mothed able to eliminate the influence of complex lithology, complex pore structure and to thick host rock and to divide oil, gas and water reservoirs. But it is imperfect at present. Considering the basic conditions that mud filtrate intrudes into the strata profiles and the different intruding profiles of reservoir with intergranular pores, fractured reservoir, oil-gas reservoir, a qualitative and quantitative interpretatin method for resistivity time-lapse logging is presented. The influence of mud resistivity and relative density variation may not be considered in reservoir with intergranular pores. However, the two factors should be taken into account in fractured reservoir. While logging, it is very important to know well the time for two logging. The time for the first logging is chosen when mud filtrate intrudes into the relatively shallow reservoir and the second logging when the filtrate goes into reservoir deeper. The application of this method to interpret the logging data of several wells in Talimu oil field shows that the results are coincident the testing data.

SUBJECT HEADINGS: Time-lapse logging, Reservoir, Oil-gas formation, Recognition.

Chen Fuxuan, associate professor, graduated in geophysical well logging from Beijing Petroleum Institute in 1963; At present, he is engaged in geophysical well logging teaching and research. Add: (637001) Nanchong, Sichuan. Tel: (0817)224433—2855.

Yang Weining *(Chengdu Science and Engineering College)*, Wang Hong, He Baokan, Kuang Jianchao, Zhang Gaoxin, Li Huamin, Chen Shufang: **ROLLING NERVE NETWORK MODEL AND ITS APPLICATIN TO NATURAL GAS PRODUCTIVITY FORECAST, NGI** 16(1), 1996: 29~32

ABSTRACT: A rolling nerve network model and the ordered derivative concept are introduced. The network redlization process is discussed. The forecast model of natural gas productivity constructed by use of a rolling BP network is presented. It has been verified that the computed results of the model met the accuracy of numeral simulation, and the natural gas productivity in new areas can be forecast.

SUBJECT HEADINGS: Rolling BP network, Ordered derivative, Numeral simulation, Productivity, Forecast.

Yang Weining: lecturer, graduated in applied mathematics from Chengdu University of Science and Engineering with Masters degree in 1989; She is engaged in the applied researches on computers and information sciences in geology; Add: (610059) Shilidian, Chengdu. Tel: (028)3334712—3075.

Jiang Wei *(Drilling Department of Bohai Company, CNOPC Oil Corporation)*: **PRACTICES OF DRILLING THE WELLS WITH MIDDLE CURVATURE AND LARGE INCLINATION IN BOHAI GRANITE FORMATION, NGI** 16(1), 1996: 32~35

ABSTRACT: A very difficult directional well with middle curvature and large inclination, the biggest doglegging of 21.2°/30 m, hole deviation of 75° and horizontal section of 271.21 m, deflecting at 2 617 m and running through granite formation of 73 m, was drilled by Bohai Company, CNOPC five techniques such as MWD survey, top drive drilling, deflecting in hard formation by use of accordant direction and double bend motor, controlling well track in granite formation and MMH mud have been used to make the whole operation safe and smooth. The practical experience concerning the drilling tool texture, penetration rate, bit service, technology etc. are summarized to accumulate abundant experiences for drilling the horizontal wells with large inclination in granite formation.

SUBJECT HEADINGS: Bohai bay, Granite, Directional well, Middle curvature, High angle deviated hole, Drilling technology.

Wang Junliang *(Drilling and Production Technology Research Institute of Sichuan Petroleum Administration)*: **A PRELIMINARY PROBE INTO THE RATIONAL SELECTION OF DIRECTIONAL WELL STABILIZERS, NGI** 16(1), 1996: 36~38

ABSTRACT: According to the working characteristics of stabilizer during drilling and concrete conditions of soft and hard formations, the forced situations of the stabilizers in various conditions are analysed to achieve the anticipated deflecting results, safely reaming and successfully making a round trip. The method of rationally selecting stabilizers in soft and hard formations is presented.

SUBJECT HEADINGS: Directional well, Stabilizer, Bottom hole assembly, Drilling technology.

Wang Junliang, engineer, graduated in drilling from Southwest Petroleum Institute in 1985; Add: (641202) Zizhong, Sichuan. Tel: (08418)522579—2053.