分形裂缝气藏不稳定渗流问题探讨

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摘 要 将非线性学分形理论引入渗流力学问题，引入双参数(D,θ)来描述油气藏的分形特征，分形维数D反映了分形体的几何特征，是分形体复杂程度的重要标志；分形指数θ描述了分形网络的连通情况，与谱维数有关。建立了分形气藏的理想气体与真实气体不稳定渗流模型，用拉氏变换求出分形气藏渗流模型无穷大地层解及长、短时渐近解。该模型是非线性理论分形几何应用于渗流力学的一个重要课题。

主题词 裂缝性油气藏 气藏 不稳定 渗流 分形学 理论 拉普拉斯变换

科学家们在对裂缝气藏和均质气藏研究中提出了许多裂缝和孔隙结构模型，这些模型的数学基础是欧几里得几何，均采用均质手段或拟均质处理方法，近似反映了裂缝和多孔介质的性质。然而实际气藏裂缝分布或孔隙结构是相当复杂的，对于非欧几里得裂缝网络和非均质多孔介质，这些模型就不太适用了，因此，需要选择另外的模型，而分形几何则是模拟裂缝网络和非均质多孔介质的有效工具。

分形是当代非线性学科的一个前沿课题。它是描述粗糙的、不规则的、复杂的且具有自相似或自仿射规律形体的有力工具，其基本特征是尺度不变性。油气藏工程和渗流力学中的许多现象都具有尺度不变性，如渗透率分布，孔隙分布、裂缝油气藏中的裂缝网络分布。以分形理论为基础，建立的分形孔隙模型和分形裂缝网络模型[1~3]恰好可以弥补传统理想模型的缺陷，是对实际气藏非均质性的进一步近似描述。引入双参数(D,θ)来刻画油气藏的分形特性，分形维数D反映了分形体的几何特征，是分形体复杂程度的重要标志，D的值越高，复杂程度愈高，分形指数(θ)(也称反常扩散指数，与谱维数有关)[4]描述了分形网络的连通情况，分形网络越扭曲复杂，通性越差，θ越高。同时θ也赋于动态信息——反映渗流发生在分形网络时的异常，本文将分形几何引入渗流力学，建立了分形气藏的理想气体和真实气体的渗流模型，用Laplace变换求出了此模型的解，给出了渐近解。

理想气体的不稳定渗流

天然气与石油在分形油气藏中的渗流有许多共同点，但也有其自身的特点。我们以主要因素为主，忽略次要因素，描述分形气藏的不稳定渗流规律。假定：①地层是分形裂缝网络嵌入d维欧几里得岩块中，渗流只发生在裂缝网络中，即发生流动的那部分介质是分形的；②气藏温度不变；③理想气体，粘度为常数；④压力梯度小；⑤服从达西定律。

连续方程为：

$$V_sN(r)\left(\frac{\partial\rho}{\partial t}\right)+\frac{\partial(\rho\,Q_r)}{\partial r}=0 \tag{1}$$

其中V_s是典型单元体的体积，$N(r)$是单元体密度，且$N(r)=ar^{D-1}$，Q_r为体积流量。

状态方程为：

$$\rho=\frac{\rho_i}{p_i}p \tag{2}$$

运动方程[1]为：

$$q_r=-[aV_sm/(G\mu)]r^{D-d-\theta}\ \frac{\partial p}{\partial r} \tag{3}$$

其中a直接与它的裂缝孔隙度有关；G描述某种相应的对称性(如$G=A$，$2\pi h$和4π分别描述线性柱和球对称三种情形)；m是几何形态参数，它表达介质的连续性和导流性；θ是分形指数，它的物理意义是刻画分形体中渗流发生时相对于经典整形体的扩散变异程度，标明分形网络的连通情况，且原则上由物

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体的结构确定。流量(Q_r)与流速(q_r)有关：

$$Q_r = G r^{d-1} q_r \tag{4}$$

将式(2)、(3)、(4)代入式(1)得：

$$C r^{D-1}\frac{\partial p^2}{\partial t} = \frac{m}{\mu}\,\frac{\partial}{\partial r}\left(r^{\beta}\,\frac{\partial p^2}{\partial r}\right) \tag{5}$$

其中 $\beta = D-\theta-1$；$C=\frac{1}{p}$。方程(5)是非线性偏微分方程，用平均压力($\bar{p}$)，$C\approx\frac{1}{\bar{p}}$[5]，因此，分形气藏理想气体不稳定渗流的定解问题为：

$$\frac{C\mu}{m}\,\frac{\partial p^2}{\partial t} = \frac{1}{r^{D-1}}\,\frac{\partial}{\partial r}\left(r^{\beta}\frac{\partial p^2}{\partial r}\right) \tag{6}$$

$$p^2|_{t=0} = p_i^2 \tag{7}$$

$$\frac{aV_s m}{2\mu}\left[r^{\beta}\,\frac{\partial p^2}{\partial r}\right]\Big|_{r=r_w} = qp \tag{8}$$

$$\lim_{r\to 0} p^2 = p_i^2 \tag{9}$$

状态方程也可写成：

$$pq = \frac{p_{sc}\,Q_{sc}\,\bar{Z}T}{T_{sc}} \tag{10}$$

无量纲定义：$r^* = r_w$

$$t^* = \frac{C\mu r_w^{\theta+2}}{m}$$

$$p^* = \frac{2p_{sc}Q_{sc}\bar{Z}T\mu r_w^{1-\beta}}{T_{sc}aV_s m}$$

$$p_D^2 = \frac{p_i^2 - p^2}{p^*}$$

$$r_D = r/r^*$$

$$t_D = t/t^*$$

分形气藏天然气不稳定渗流数学模型：

$$\frac{\partial p_D^2}{\partial t_D} = \frac{\partial^2 p_D^2}{\partial r_D^2} + \frac{\beta}{r_D}\,\frac{\partial p_D^2}{\partial r_D} \tag{11}$$

$$p_D^2(r_D,t_D)|_{t_D=0} = 0 \tag{12}$$

$$\left[r_D^{\beta}\frac{\partial p_D^2}{\partial r_D}\right]\Big|_{r_D=1} = -1 \tag{13}$$

$$\lim_{r_D\to\infty} p_D^2 = 0 \tag{14}$$

对式(11)～(14)作拉氏变换得：

$$r_D^{\theta}\,S\,\bar{p}_D^2 = \frac{d^2\bar{p}_D^2}{dr_D^2} + \frac{\beta}{r_D}\,\frac{d\bar{p}_D^2}{dr_D} \tag{15}$$

$$\frac{d\bar{p}_D^2}{dr_D}\Big|_{r_D=1} = -\frac{1}{S} \tag{16}$$

$$\lim_{r_D\to\infty}\bar{p}_D^2 = 0 \tag{17}$$

对式(15)作变换：

$$\bar{p}_D^2 = r_D^{\frac{1-\beta}{2}} f\left(\sqrt{S}\;r_D^{\frac{\theta+2}{2}}\right)$$

$$\rho = \sqrt{S}\,r^{\frac{\theta+2}{2}}$$

则方程(15)化为：

$$\rho^2\frac{d^2 f}{d\rho^2} + \rho\frac{df}{d\rho} - \left[(1-\delta)^2 + \left(\frac{2\rho}{\theta+2}\right)\right]f = 0$$

由此可得方程(15)的通解

$$\bar{p}_D^2 = C_1 r_D^{\frac{1-\beta}{2}} I_v\left(\frac{2\sqrt{S}}{\theta+2}r_D^{\frac{\theta+2}{2}}\right) + C_2 r_D^{\frac{1-\beta}{2}} K_v\left(\frac{2\sqrt{S}}{\theta+2}\,r_D^{\frac{\theta+2}{2}}\right)$$

其中：$\delta = \frac{D}{\theta+2}$，$v = 1-\delta$。

由式(16)、(17)得

$$\bar{p}_D^2 = \frac{r_D^{\frac{1-\beta}{2}} K_v\left(\frac{2\sqrt{S}}{\theta+2}r_D^{\frac{\theta+2}{2}}\right)}{S^{3/2}K_{v-1}\left(\frac{2\sqrt{S}}{\theta+2}\right)} \tag{18}$$

$$\bar{p}_D^2(1,S) = \frac{K_v\left(\frac{2\sqrt{S}}{\theta+2}\right)}{S^{3/2}K_{v-1}\left(\frac{2\sqrt{S}}{\theta+2}\right)} \tag{19}$$

设 $F(S) = S\bar{p}_D^2(1,S)$

其原函数

$$f(t_D) = \frac{1}{2\pi i}\int_{\gamma-i\infty}^{\gamma+i\infty}\frac{K_v\left(\frac{2\sqrt{S}}{\theta+2}\right)}{S^{1/2}K_{v-1}\left(\frac{2\sqrt{S}}{\theta+2}\right)}e^{S t_D}\,dS$$

选择积分围道如图1所示。

由约当引理及其推论有

$$f(t_D) = -\lim_{\substack{r\to 0\\ R\to\infty}}\frac{1}{2\pi i}\left(\int_{I} + \int_{I}\right)$$

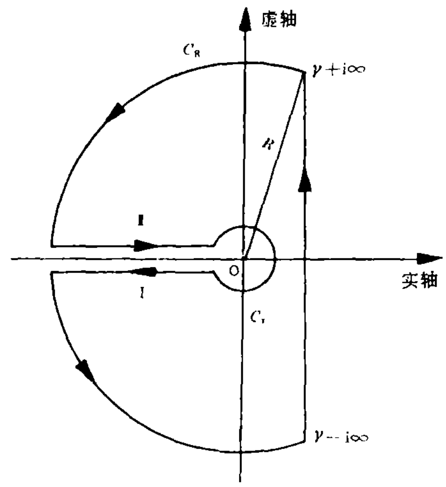

图1　积分围道

Fig. 1. Integral contour.

在割缝上部，取 $S = z^2 e^{i\pi}$，$\sqrt{S} = zi$，$m = \frac{2}{\theta+2}$

$$-\int_{I} = \int_0^{\infty}\frac{K_v(mzi)}{ziK_{v-1}(mzi)}\left(-2ze^{-z^2t_D}\right)dz = -\frac{2}{i}\int_0^{\infty}\frac{K_v(mzi)}{K_{v-1}(mzi)}e^{-z^2t_D}dz$$

在割缝下部，$S = z^2e^{-i\pi}$，$\sqrt{S} = -zi$。

$$-\int_{I} = -\frac{2}{i}\int_0^{\infty}\frac{K_v(-mzi)}{K_{v-1}(-mzi)}e^{-z^2t_D}dz$$

注意到 $K_v(iz)=-\frac{\pi}{2}ie^{-\frac{v\pi}{2}}[J_v(z)-iY_v(z)]$

$$K_v(-iz)=\frac{\pi}{2}ie^{\frac{v\pi}{2}}[J_v(z)+iY_v(z)]$$

$$f(t_D)=\frac{2(\theta+2)}{\pi^2}\int_0^\infty \frac{e^{-z^2t_D}}{J_{v-1}^2\left(\frac{2}{\theta+2}z\right)+Y_{v-1}^2\left(\frac{2z}{\theta+2}\right)}\frac{dz}{z}$$

$$p_D^2(1,t_D)=\frac{2(\theta+2)}{\pi^2}\int_0^\infty \frac{(1-e^{-z^2t_D})dz}{z^3\left[J_{v-1}^2\left(\frac{2z}{\theta+2}\right)+Y_{v-1}^2\left(\frac{2z}{\theta+2}\right)\right]} \tag{20}$$

由 Laplace 变换性质，象函数 $S\to\infty$ 时的渐近展开对应着函数 $t_D\to 0$ 时的一个渐近展开，而当 $x\to\infty$ 时有下面近似式：

$$K_v(x)=K_{1-\delta}(x)\sim\sqrt{\frac{\pi}{2x}}e^{-x}\left[1+\frac{(3/2-\delta)(1/2-\delta)}{2x}-\right.$$
$$\left.-\frac{(5/2-\delta)(3/2-\delta)(1/2-\delta)(1/2+\delta)}{4x^2}+o\left(\frac{1}{x^3}\right)\right]$$

$$K_{v-1}(x)=K_{-\delta}(x)=K_\delta(x)\sim\sqrt{\frac{\pi}{2x}}e^{-x}\left[1+\frac{(\delta+1/2)(\delta-1/2)}{2x}+\right.$$
$$\left.+\frac{(\delta+3/2)(\delta+1/2)(\delta-1/2)(\delta-3/2)}{4x^2}+o\left(\frac{1}{x^3}\right)\right]$$

并注意到等式：

$$\frac{a_0+a_1u+a_2u^2+a_3u^3+\cdots}{b_0+b_1u+b_2u^2+b_3u^3+\cdots}=C_0+C_1u+C_2u^2+C_3u^3+\cdots$$

$$C_0=\frac{a_0}{b_0},C_1=\frac{(a_1-C_0b_1)}{b_0},C_2=\frac{(a_2-C_0b_2-C_1b_1)}{b_0}$$

代入式(19)得：

$$\bar{p}_D^2\sim\frac{1}{S^{3/2}}\left[1+\frac{(1-2\delta)(\theta+2)}{4\sqrt{S}}+\right.$$
$$\left.+\frac{(2\delta+1)(2\delta-1)(5-2\delta)(\theta+2)^2}{64S}+o(1/S^{3/2})\right]$$

查表求反变换得：

$$p_D^2\sim 2\sqrt{\frac{t_D}{\pi}}+\frac{(\theta+2-2D)}{4}t_D+$$
$$+\frac{[4D^2-(\theta+2)^2](5-2\delta)}{64\Gamma(S/2)}t_D^{3/2}+o(t_D^2) \tag{21}$$

当时间很短时，只有第一项是重要的，此时上式简化为：

$$p_D^2\sim 2\sqrt{\frac{t_D}{\pi}} \tag{22}$$

当 $S\to 0$ 时，对应着 $t_D\to\infty$ 的一个渐近展开，而当 $S\to 0$ 时有近似式：

$$K_v\left(\frac{2\sqrt{S}}{\theta+2}\right)=K_{1-\delta}\left(\frac{2\sqrt{S}}{\theta+2}\right)\sim\frac{2^{-\delta}\Gamma(1-\delta)}{\left(\frac{2\sqrt{S}}{\theta+2}\right)^{1-\delta}}$$

$$0<v<1$$

$$K_{v-1}\left(\frac{2\sqrt{S}}{\theta+2}\right)=K_{-\delta}\left(\frac{2\sqrt{S}}{\theta+2}\right)=K_\delta\left(\frac{2\sqrt{S}}{\theta+2}\right)\sim\frac{2^{\delta-1}\Gamma(\delta)}{\left(\frac{2\sqrt{S}}{\theta+2}\right)^\delta}$$

将上面两式代入式(19)，并进行拉氏反演，得长时渐近解

$$p_D^2(1,t_D)\approx\frac{(\theta+2)^{2(1-\delta)}}{(\theta+2-D)\Gamma(\delta)}t_D^{1-\delta} \tag{23}$$

当采用有量纲井底压力

$$p_w^2(t)=p_i^2-\frac{4(\theta+2)p_{sc}Q_{sc}\bar{Z}T\mu r_w^{1-\beta}}{\pi^2T_{sc}aV_sm}\times$$
$$\times\int_0^\infty\frac{\left(1-e^{-\frac{mZ^2t}{C\mu r_w^{\theta+2}}}\right)dz}{z^3\left[J_{v-1}^2\left(\frac{2z}{\theta+2}\right)+Y_{v-1}^2\left(\frac{2z}{\theta+2}\right)\right]}$$

时，得短时渐近解：

$$p_w^2(t)=p_i^2-\frac{2p_{sc}Q_{sc}\bar{Z}T\mu r_w^{1-\beta}}{T_{sc}aV_sm}\left\{2\sqrt{\frac{mt}{\pi C\mu r_w^{\theta+2}}}+\right.$$
$$\left.+\frac{(\theta+2-2D)mt}{4C\mu r_w^{\theta+2}}+\frac{[4D^2-(\theta+2)^2](5-2\delta)t^{3/2}}{64\Gamma(5/2)C^{3/2}\mu^{3/2}r_w^{\frac{3(\theta+2)}{2}}}\right\}$$

时间特别短时，有

$$p_w^2(t)=p_i^2-\frac{4p_{sc}Q_{sc}\bar{Z}T\mu r_w^{1-\beta}}{T_{sc}aV_sm}\sqrt{\frac{mt}{\pi C\mu r_w^{\theta+2}}}$$

同时得长时渐近解：

$$p_w^2=p_i^2-\frac{2p_{sc}Q_{sc}\bar{Z}T\mu r_w^{1-\beta}(\theta+2)^{2(1-\delta)}m^{1-\delta}}{T_{sc}aV_sm(\theta+2-D)\Gamma(\delta)C^{1-\delta}\mu^{1-\delta}r_w^{1-\beta}}t^{1-\delta}$$
$$(0<\delta<1)$$

真实气体不稳定渗流

在气田勘探开发中，只有当压力很低时天然气才接近于理想气体，高压时气体与理想状态差异较大。气体的压缩系数、压缩因子、粘度都随气藏的温度和压力而变化。

对真实气体，如假定条件不变则连续方程同方程(1)一样，运动方程同方程(3)一样，而状态方程为：

$$\rho=\frac{Mp}{ZRT} \tag{24}$$

气体等温压缩系数为：

$$C=\frac{1}{\rho}\frac{d\rho}{dp}=\frac{1}{p}-\frac{1}{Z}\frac{dZ}{dp} \tag{25}$$

真实气体的定解问题描述如下：

令压力函数：

$$m_1(p)=2\int_0^p\frac{p\,dp}{\mu(p)Z(p)} \tag{26}$$

则：$\frac{\partial m_1(p)}{\partial r}=\frac{2p}{\mu Z}\frac{\partial p}{\partial r}$　　$\frac{\partial m_1(p)}{\partial t}=\frac{2p}{\mu Z}\frac{\partial p}{\partial t}$

将运动方程、状态方程和上两式代入连续方程得：

$$\frac{\partial m_1(p)}{\partial t}=\frac{m}{\mu c}\frac{1}{r^{D-1}}\frac{\partial}{\partial r}\left[r^\beta\frac{\partial m_1(p)}{\partial r}\right] \tag{27}$$

上式也是一个非线性方程，由假定④把压缩系数 C 看为常数[5]，认为粘度与压力关系不大，用平均值代替[6]。则真实气体的定解问题为：

$$\frac{\partial^2m_1(p)}{\partial r^2}+\frac{\beta}{r}\frac{\partial m_1(p)}{\partial r}=\frac{m}{\mu C}r^\theta\frac{\partial m_1(p)}{\partial t} \tag{28}$$

$$m_1(p)\big|_{t=0}=m_1(p_i) \quad (29)$$

$$\left[r^{\beta}\frac{\partial m_1(p)}{\partial r}\right]_{r=r_w}=\frac{2qp}{ZaV_sm} \quad (30)$$

$$\lim_{r\to\infty} m_1(p)=m_1(p_i) \quad (31)$$

$$\frac{pq}{Z}=\frac{p_{sc}Q_{sc}T}{T_{sc}} \quad (32)$$

其中：$m_{1D}(p)=\frac{T_{sc}aV_sm}{2P_{sc}Q_{sc}T}\gamma_W^{1-\beta}[m_1(p_i)-m_1(p)]$

$r_D=\frac{r}{r_w}$　　$t_D=\frac{mt}{C\mu r_w^{\theta+2}}$

那么，分形气藏真实气体不稳定渗流数学模型为：

$$r_D^{\theta}\frac{\partial m_{1D}(p)}{\partial r_D}=\frac{\partial^2 m_{1D}(p)}{\partial r_D^2}+\frac{\beta}{r_D}\frac{\partial m_{1D}(p)}{\partial r_D} \quad (33)$$

$$m_{1D}(p)\big|_{t_D=0}=0 \quad (34)$$

$$\left[r_D^{\beta}\frac{\partial m_{1D}(p)}{\partial r_D}\right]\Big|_{r_D=1}=-1 \quad (35)$$

$$\lim_{r_D\to\infty} m_{1D}(p)=0 \quad (36)$$

同样按照前面的求解过程，用 Laplace 变换求得：

$$m_{1D}(p)=\frac{2(\theta+2)}{\pi^2}\int_0^{\infty}\frac{(1-e^{-z^2t_D})dz}{z^3\left[J_{v-1}\left(\frac{2z}{\theta+2}\right)+Y_{v-1}^2\left(\frac{2z}{\theta+2}\right)\right]} \quad (37)$$

短时渐近解为：

$$m_{1D}(p_{ws})\approx 2\sqrt{\frac{t_D}{\pi}}+\frac{(\theta+2-2D)}{4}t+ +\frac{[4D^2-(\theta+2)^2](5-2\delta)}{64\Gamma(5/2)}t_D^{\frac{3}{2}}$$

当时间特别短时，即有

$$m_{1D}(p_{ws})\approx 2\sqrt{\frac{t_D}{\pi}}$$

长时渐近解为：

$$m_{1D}(p_{ws})\approx\frac{(\theta+2)^{2(1-\delta)}}{(\theta+2-D)\Gamma(\delta)}t_D^{1-\delta}$$

当采用有量纲井底压力

$$m_1(p_{ws})=m_1(p_i)-\frac{4(\theta+2)p_{sc}Q_{sc}T\gamma_W^{1-\beta}}{\pi^2T_{sc}aV_sm\gamma_W^{1-\beta}}\times \int_0^{\infty}\frac{(1-e^{-\frac{z^2mt}{C\mu r_w^{\theta+2}}})dz}{z^3\left[J_{v-1}^2\left(\frac{2z}{\theta+2}\right)+Y_{v-1}^2\left(\frac{2z}{\theta+2}\right)\right]}$$

时，得长时渐近解：

$$m_1(p_{ws})=m_1(p_i)-\frac{2(\theta+2)^{2(1-\delta)}m^{1-\delta}t^{1-\delta}p_{sc}Q_{sc}T}{(\theta+2-D)\Gamma(\delta)C^{1-\delta}\mu^{1-\delta}T_{sc}aV_sm}$$

同时得短时渐近解：

$$m_1(p_{ws})=m_1(p_i)-\frac{2p_{sc}Q_{sc}T\gamma_W^{1-\beta}}{T_{sc}aV_sm}\left\{2\sqrt{\frac{mt}{\pi C\mu r_w^{\theta+2}}}+\frac{(\theta+2-2D)mt}{4C\mu r_w^{\theta+2}}+\frac{[4D^2-(\theta+2)^2](5-2\delta)t^{3/2}}{64\Gamma(5/2)C^{3/2}\mu^{3/2}r_w^{\frac{3(\theta+2)}{2}}}\right\}$$

当时间特别短时，即：

$$m_1(p_{ws})=m_1(p_i)-\frac{4p_{sc}Q_{sc}T\gamma_W^{1-\beta}}{T_{sc}aV_sm}\sqrt{\frac{mt}{\pi C\mu r_w^{\theta+2}}}$$

由于篇幅所限，对于分形气藏理论的应用及其通过试井分析反求分形参数将在另文中讨论。

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墨西哥发明高灵敏度天然气泄漏检测器

墨西哥发现了一种高灵敏度天然气泄漏检测器，它能在天然气泄漏后的40秒钟内迅速作出反应。据墨西哥尤卡坦科学研究中心专家马尔克斯介绍，这种检测器实际上是一种用既能导电又能与天然气发生反应的聚合物制成的电线，其直径为2毫米。在正常情况下电线导电，但遇天然气后，聚合物与其发生反应而熔化，便出现短路，这样就可立即发现漏气问题。该检测器还能用于汽车加油站油箱漏油检测。

国　信

evolution,Formation evaluation.

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Zhao LiangXiao (*Logging Company of Sichuan Petroleum Administration*): **MECHANISM OF FRACTURING AND LEAKAGE CAUSED BY HEAVY MUD AND DIAGNOSIS BY LOGGING,NGI** 16(2),1996:19~22

ABSTRACT:There are 2 reasons that cause the loss of drilling mud ,one is through the natural permeable formation and the other is through the fractures caused by heavy mud. As the induced fractures penetrate a long distance in the formation,the mud loss is serious and hard to prevent,so the drilling process are greatly affected. The mechanism of fracturing and leakage caused by heavy mud is the existance of various kinds of stress in the downhole. As the density of mud is great enough,these stresses will form the tensile stress that will cause the tension fracture along the maximum major stress on the well wall. Based on this mechanism,we know that these artificial fractures are high-angle fractures with a long longitudinal distance along the maximum major stress. This kind of fractures has special log response,that is"double trace"phenomenon in deep-shallow dual laterolog. Based on dual laterlog and some log data about imaging, well temperature and fluid,the zone and properties of mud loss can be determined.

SUBJECT HEADINGS:Drilling fluid pressure,Fracturing fracture,Mechanism,Log interpretation.

Chen Yuanqian(*Exploration and Development Research Institute of China National Petroleum Corporation*):**DERIVATION AND APPLICATION OF WENG' S PREDICATION MODEL,NGI** 16(2),1996:22~26

ABSTRACT:The generalized Weng' s predication model is derived based on the x^2 distribution in probability statistics. This model can be used to predict production rate,recoverable reserves,maximum annual output and its occuring time,in addition,the linear solution for the model is provided in the paper. Application of Weng' s model in two oil fields indicates that this model is practical and efficient.

SUBJECT HEADINGS:Model,Prediction,Production,Recoverable reserves.

Tong Dengke (*Petroleum University*) Ge Jiali: **UNSTABLE PERCOLATION FLOW ASSOCIATE WITH FRACTAL FPACTURED POOL,NGI** 16(2),1996:27~30

ABSTRACT:To solve the mechanical problems associate with percolation flow,the nonlinear fractal theory is employed,and dual parameters(D,θ)are introduced to describe the fractal characteristics of the reservoir. Fractal dimension D reflects the geometric characteristics of fractal system;fractal exponent θ shows the connectedness of fractal network and is related to Prandtl number. In addition,the unstable percolation model of ideal and real gas for fractal reservoirs is built,based on this model,the infinite stratigraphic solution and long/short-rate asymptotic solution are get by Laplace transform. The model is an important application of nonlinear fractal theory in percolation mechanics.

SUBJECT HEADINGS:Fractal pool,Gas reservoir,Instability,Fractal,Theory,Laplace transform.

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Zhang Liehui(*Southwest Petroleum Institute*)He Wei:**DYNAMIC NUMERICAL SIMULATION OF**